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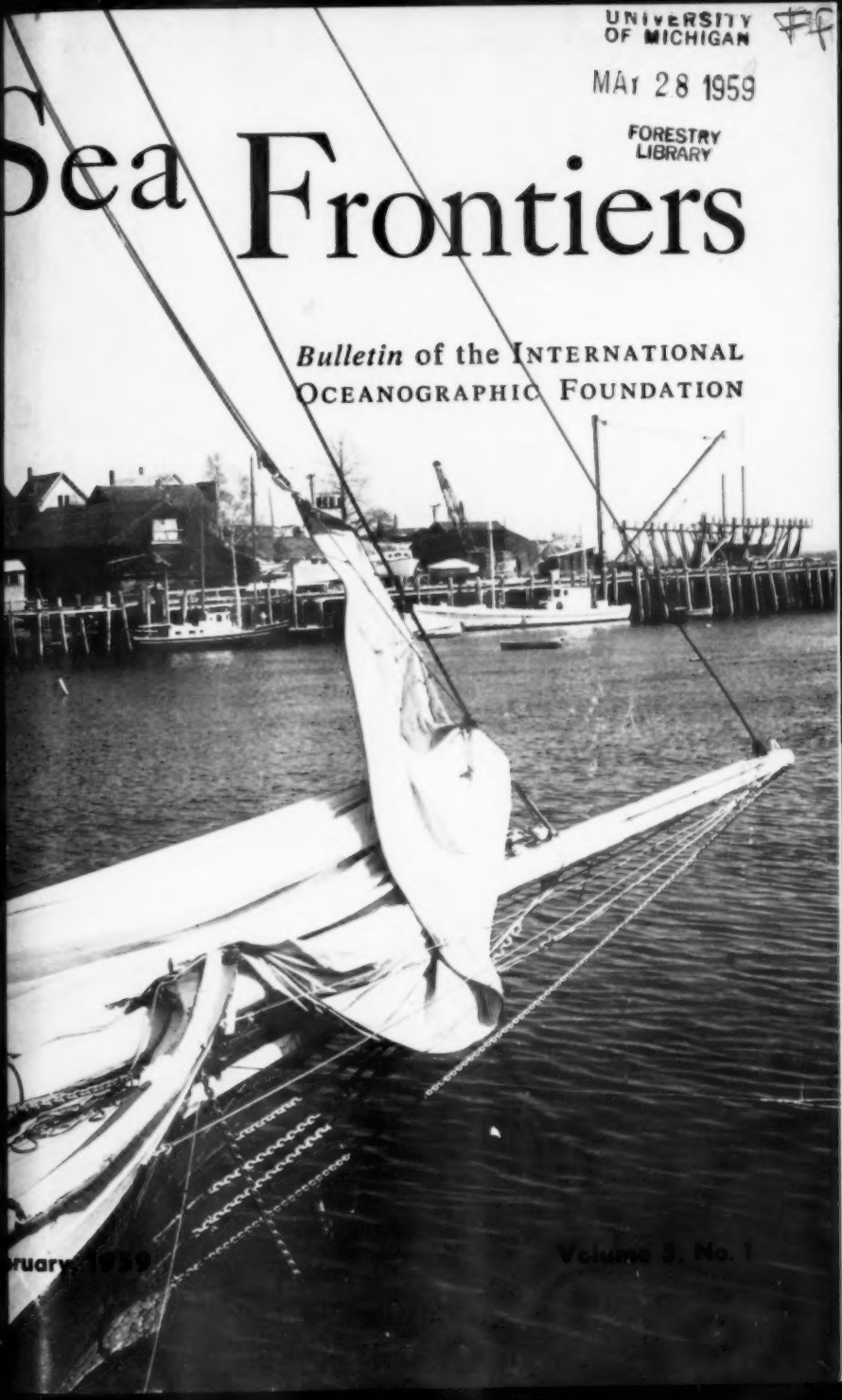
Sea Frontiers

Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION



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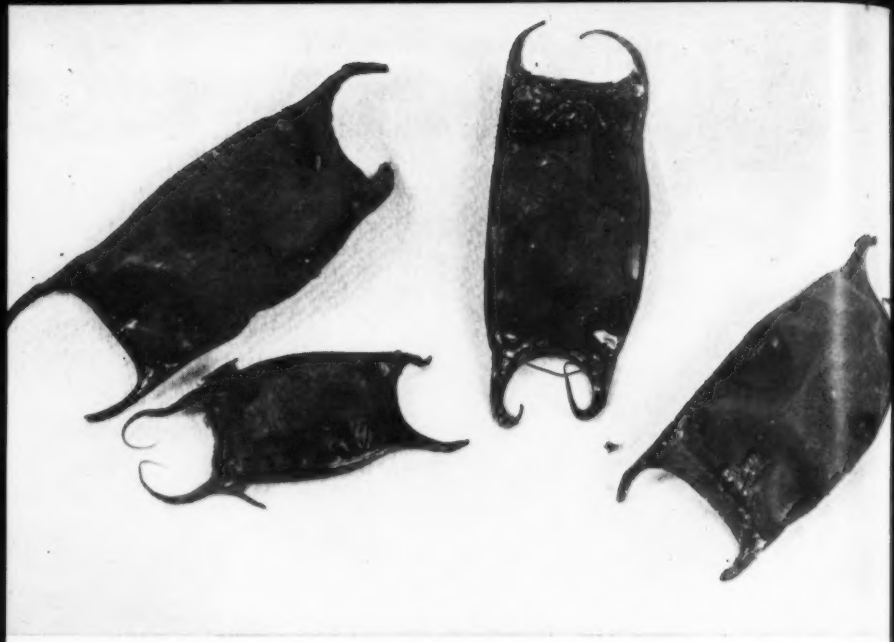

LITTLE SEA BATS? *Or perhaps a seed burr from a land plant or bush? No, these are actually the egg cases of devilfish or skates, quite common along the beaches of the Gulf and Atlantic seacoasts of the United States. Also known as "mermaid's purses," these horny capsules each contain an egg of a skate, which is a type of ray. (Marine Laboratory, University of Miami)*

FRONT COVER. *The fishing fleet has returned from one of its periodic battles with the sea, and an air of repose settles over the quaint harbor of Camden, Maine. Foresails dry in the bright sunlight. (Maine Department of Sea and Shore Fisheries)*

BACK COVER. *Patterns in the sea. Only when viewed from beneath the waves is it possible fully to appreciate the symmetry and beauty of a school of fish. The instincts and behavior mechanisms which are involved in the schooling of fishes are of especial interest to marine biologists. (Marine Studios, Marineland, Florida)*

SEA FRONTIERS

Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION

Editor: F. G. Walton Smith
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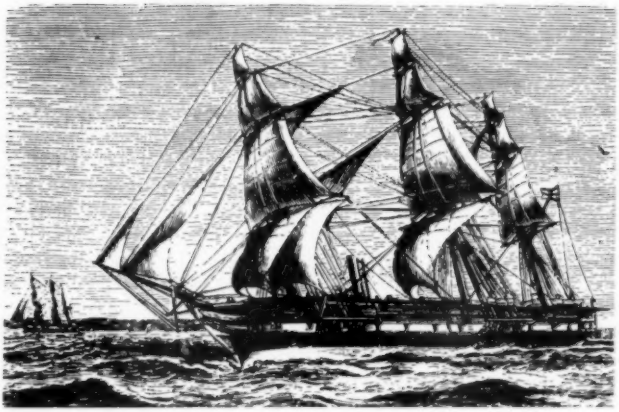

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SHRIMP BOATS ARRIVE AT MARATHON, *in the Florida Keys, and workers are busily processing the catch for shipment by refrigerated trucks to Miami and elsewhere. In June, 1958, the Shrimp Association of the Americas formed a Conservation Committee to consider methods of promoting the welfare of their industry by maintaining shrimp stocks. Its work will be directed toward proper* use *of shrimp resources rather than mere* restrictions, *which often result in less fishing and smaller catches. (E. John Long)*

Conservation Can Be Positive, Too

In June, 1958, one of the big fishery trade groups, the Shrimp Association of the Americas, formed a Conservation Committee to consider methods of promoting the welfare of their industry by maintaining the shrimp stocks.

This move on the part of the leaders of the fishing industry is a healthy one, which can result in much benefit to themselves and to the natural wealth of the countries involved. It is also an encouraging sign to professional fishery scientists, who cannot work effectively to promote the welfare of the fisheries without the active interest and support of the industry which exploits the resource.

Doubt About Term Unfounded

However, a problem arose soon after the Committee was created. This was the doubt expressed by many Association members as to whether "Conservation" was a proper and suitable name for the new committee. This doubt illustrates neatly a misunderstanding about conservation generally, and fishery conservation in particular, which prevails widely, and which clouds fisheries research activities to an extent sometimes damaging to science and commerce alike.

This misunderstanding is that conservation always implies *restriction*—that inevitably less fishing and smaller catches follow fishery conservation programs. As a matter of fact this need not and frequently is not true.

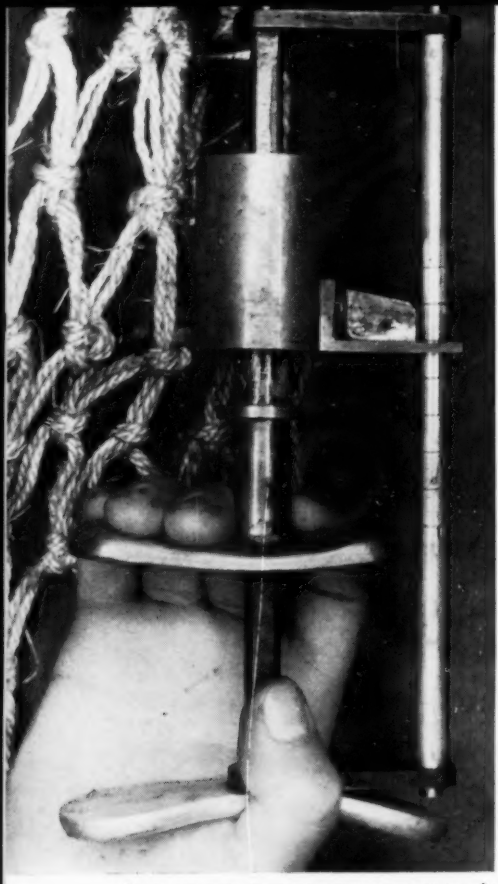
There are many different legitimate definitions of conservation and some of them do involve restrictive laws. This is especially true where rare or disappearing species are involved, or where the resource is being protected for display purposes, as in the national parks. This kind of conservation is, perhaps, the oldest kind, and it is not too surprising that fishery conservation becomes popularly associated with such an historic idea.

Actually, good fishery conservation implies use. This, and not restriction, is the key word, and it will serve a useful purpose if we can spread this concept a little more widely.

"Maximum Sustained Yield"

All professions have their jargon, and the phrase "maximum sustained yield" is part of the special language of the fishery biologist. In more familiar terms this means the greatest amount of fish which can safely be caught over many years — in theory indefinitely. "Indefinitely" is another key word, because one of the great advantages of being in a business which exploits a living resource is that with wise management the resource need never disappear as oil or copper deposits eventually will. It implies the expenditure of income, rather than capital.

Conservation of a fishery resource, then, involves the managing of the fish stock so that the greatest possible amount may be derived from it. Sometimes, it is true, in order to get the greatest profit from the fishery over the long pull it may be necessary to



ONE OF THE RESTRICTIVE MEASURES *in fisheries conservation is the adoption of a minimum mesh size for trawl and other nets, thereby allowing smaller, unmarketable fish to escape and grow. Gauges like this one are used to measure the openings. Other restrictions involve rare or disappearing species, or fishes being protected for display purposes, as in the National Parks. (Robert Ellis)*

restrict catches in a given year; frequently, however, it may be clear from research that *more fish* can actually be safely harvested.

Underfishing is Possible

That *underfishing* can actually occur is a strange idea which some people never can accept. But it is nonetheless extremely important to an understanding of the true meaning of fishery conservation, because it shows the danger of casual tampering with fishing operations by imposing restrictions without good evidence of their need.

Conservation is everybody's business and this is made quite plain when one listens to a group at a noonday service club luncheon, a Boy Scout meeting, a rod and gun club dinner or a commercial fishermen's union meeting. This is as it should be; everyone has a vested interest in conservation and should be aware of the problems.

Job for Professionals

But it becomes dangerous if these groups fail to recognize that conservation and its application, fishery management, is a highly technical subject which must, in the final analysis, be left to professionals. Few ordinary citizens would offer their services to perform brain surgery or design an interplanetary rocket, but the number of self-appointed experts in fishery conservation would form a line from here to there—and frequently does!

Fisheries biology is a young science. The amount still to be learned is far greater than the amount of knowledge already at hand. As a consequence, scientists are apt to delay action on restrictive legislation, knowing the damage that can be done by overhasty action.

Trial and Error Laws?

Fishermen are understandably impatient at this attitude, especially if they can see or think they see their

CAREFUL RESEARCH *and factual knowledge should be available before restrictions are applied to the sea fisheries, in order that production is not needlessly curtailed, with sharks becoming the beneficiaries. Temperature measurements as shown above may give clues to factors other than human ones, which cause sudden scarcities of fish. (Woods Hole Oceanographic Institution)*

livelihood slipping away through what seems to be lack of decision on the part of those in charge. Since the accumulation of biological knowledge is a slow and painful process it is often impractical to wait until proof of the need for regulation of a fishery is available.

Instead, trial and error regulations might be hazarded, *but only if provision can be made to test with full scientific accuracy the actual effect of the regulation on the fish stock.* This is sometimes hard to do, but with care and skill, and the willingness of administrators to allow manipulation of the regulation to serve this purpose, it can be accomplished.

Major Step Forward

Like laws against murder or speeding, conservation laws must have the understanding and support of the large majority of the people they serve, or they will be ineffective. The relatively new concepts of conservation of fisheries are strange and still unacceptable to many of those most vitally concerned. That is why cre-

ation of this Conservation Committee is a major step forward.

The members of the Shrimp Association of the Americas can be confident, therefore, that their committee has a proper name: it can lead them to greater catches because fishery conservation can very well be a positive, not a negative, concept. This is the modern approach.

Tuna Keel Adapted for Ships

THE BLUEFIN TUNA, a mystery fish since the days of Aristotle, has had another of its secrets pried from it by an English shipbuilding firm. Scientists have noted and long wondered about the small horizontal keels, like the stabilizers of an airplane, which occur at the point where the tail is joined to the body of the fish. Also they have been puzzled by the tuna's ability to capture fast-swimming prey, such as the mackerel.

Mr. Edmund Watts, chairman and managing director of Watts, Watts & Company, Ltd., after extensive study of the habits and characteristics of the tuna, concluded that the small keel enabled the big fish to turn quicker, and thus gain an advantage over mackerel and other underwater speedsters.

Fitting one of the firm's new tramp freighters with a version of the tuna's keels, he found that it not only turned more easily, but gained about a half a knot in speed over her sister ships, and fuel consumption was less. The new keels are fastened to each side of the ship, immediately forward of the propeller. They are 16 feet, 3 inches long, and have a maximum width of 3 feet, 10½ inches.

SMALL HORIZONTAL KEELS, *like the stabilizers of an airplane, may enable the bluefin tuna to turn quicker, thus capturing fast-swimming prey, such as mackerel. This idea has been borrowed recently by a British ship designer for application to merchant ships. The results were surprising and beyond expectation. The vessels not only turned more easily, but gained a half knot in speed over sister ships not so equipped. Also fuel consumption was less. The keel of a tuna is indicated here just forward of the tail of a mounted specimen. (E. John Long)*

Cobra of the Sea

By CHARLES E. LANE

DURING MOST of the winter months, a prolonged onshore wind will bring hosts of the unwelcome *Physalia physalis* to the sandy beaches of the Gulf of Mexico and Western Atlantic Ocean. This is unfortunate, because of all the animals in the sea for its weight, the Portuguese man-of-war, as it is popularly known, is the most dangerous to man. Lifeguards, in fact, fear it more than the shark or the barracuda.

The attractive appearance of this relative of the jellyfishes belies its venomous nature. An unwary bather may become entangled with its long stinging tentacles in the surf. Because it looks like a harmless transparent Christmas tree ornament, in shades of beautiful purple, blue and red, an inquisitive child is likely to pick one up on the beach.

May Cause Collapse

Both bather and child may suffer painful consequences, which vary from momentary burning sensations, through intense incapacitating agony, to complete collapse and unconsciousness—depending upon the severity of the contact and on the sensitivity of the person.

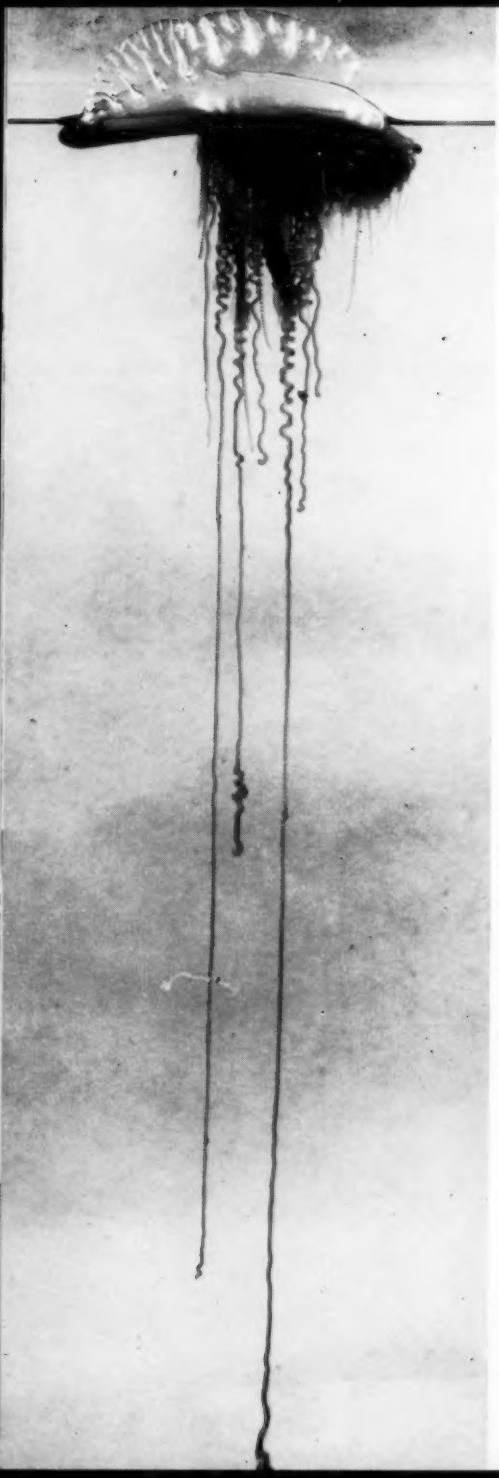
Physalia is being actively studied at The Marine Laboratory of the University of Miami to discover more about the manner of stinging, and the nature and intensity of the poison. Why is science interested? Among other reasons, because any biologically active substance, even a violent poison, may have some potential medicinal use.

Beauty of the Beach

When it is cast up on the shore by the winds and currents, and subsequently dried by the sun, *Physalia* is the prettiest thing on the beach, a bluish transparent bubble which varies in size from barely visible to several inches in diameter. But usually it is entangled with bits of seaweed, sand and other debris which obscures the true nature of the entire animal.

Observed alive at sea, *Physalia* is seen to be a complex organism, consisting of many parts. Indeed, the "animal" is more complex even than it appears to be, because a study of

WARNING! *Don't touch even small* Physalia! *Because they look like harmless Christmas tree ornaments, in beautiful shades of purple, blue and red, inquisitive persons often pick them up on the beach. But such persons may suffer painful consequences, which vary from momentary burning sensations through intense agony to complete collapse, depending upon the size of tentacles, the extent of bodily contact and the sensitivity of the person. (Charles E. Lane)*



its development reveals that it is a colonial organism, with each of its component parts representing a distinct and individual animal.

Gas-Filled Float

Most prominent of the components of the *Physalia* colony is the gaily-colored float. This is a gas-filled membranous bubble which is generally longer than it is high or thick. The composition of the contained gas, incidentally, is slightly different from that of the atmosphere—being relatively richer in carbon monoxide and poorer in oxygen.

The float bears also a showy inflated crest, like the stabilizer on a lighter-than-air blimp. This "sail," and the general boat shape of the bubble, resemble those of a tiny sailing ship, hence the common name Portuguese man-of-war.

Why "Portugal"?

The reference to Portugal is a puzzler when it is considered that *Physalia* originates in warm tropical waters, such as the Gulf of Mexico and the Caribbean Sea, although it is sometimes carried by the Gulf Stream as far north as England.

According to one explanation, *Physalia* was first sighted by English sailors moving southward with the Canaries Current, an offshoot of the

HERE IS HOW A SKIN-DIVER *might view the full length of the Portuguese man-of-war, becalmed at sea. This specimen of* Physalia physalis, *however, was photographed in a laboratory tank while studies were being made of its beautiful but dangerous stinging tentacles. Note the gas-filled float and crest, which act as a "sail" and give the appearance of a tiny galleon rig, hence* Physalia's *common name. (Charles E. Lane)*

Gulf Stream, near the coast of Portugal. As miniature fleets of *Physalia* glided along their blue crests and galleon-like appearance suggested to these first observers the name "Portuguese man-of-war," and thus it has been known (to non-scientists) since.

"Tack" Like a Sailboat?

To return to the float, this remarkable appendage can be inflated or deflated at the will of the animal. Some authorities believe that *Physalia* can actually sail a course other than straight before the wind—that it can, in fact, "tack," and so make good a course at a significant angle to that of the prevailing surface winds. Living man-of-war in the laboratory frequently roll the float under the water and bathe its entire surface. This prevents the float from drying, and may be important in gas secretion.

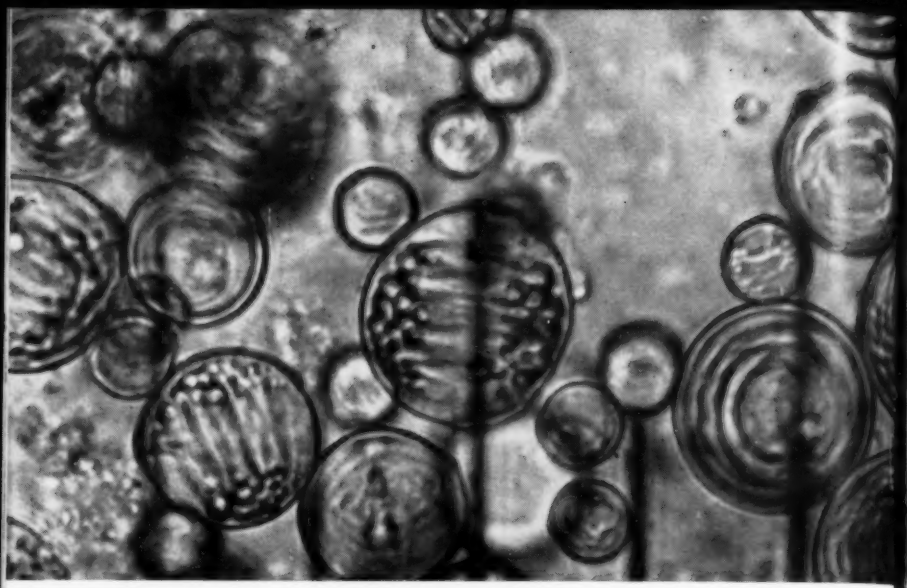
Hanging from the float, and trailing for considerable distance through the water, are many long tentacles. These tenuous, transparent threads resemble the mono-filament lines employed for the same purpose by human fishermen. They are, indeed, "fishing" tentacles, and, in an animal bearing a six-inch float, may exceed ten feet in length. Really large specimens have been reported with tentacles nearly forty feet long.

Bring Prey to Mouths of Colony

These tentacles are muscular, and can be contracted completely to bring entangled prey organisms into the many mouths of the colony. The mouths, in turn, lead into the digestive members of the colony—the gastrozooids. It has recently been shown that these are stimulated to activity by the presence of the substance glutathione in the injured prey organism. *Physalia* can be induced to attempt to feed on filter paper, or glass, which has been dipped in a dilute solution of this chemical.

Glutathione, the substance that stimulates this reaction, is very widely distributed among plant and animal tissues. It appears to be a constituent of, or to contribute to the activity of

UNDER A MICROSCOPE *the tentacles of the Portuguese man-of-war appear to be beaded. A microscopic section shows each bead as a kidney shaped object containing numerous globules. The beads are, in fact, "batteries." The contained globules are tiny stinging cells, whose normal function is to capture planktonic organisms and small fish which serve the animal for food. Biologists call the cells nematocysts. (Charles E. Lane)*



STINGING CELLS CLUSTER *along the entire length of a winding man-of-war tentacle. These fluid-filled bladder-like cells contain a hollow coiled tube. The photograph shows some of them removed in the laboratory for microscopical examination. The poison they hold is about as toxic as crude cobra venom. It is fortunate that* Physalia *cannot inject as much venom as the snake—else they would surely eliminate ocean bathing along some of our best tropical beaches during the winter tourist season. (Charles E. Lane)*

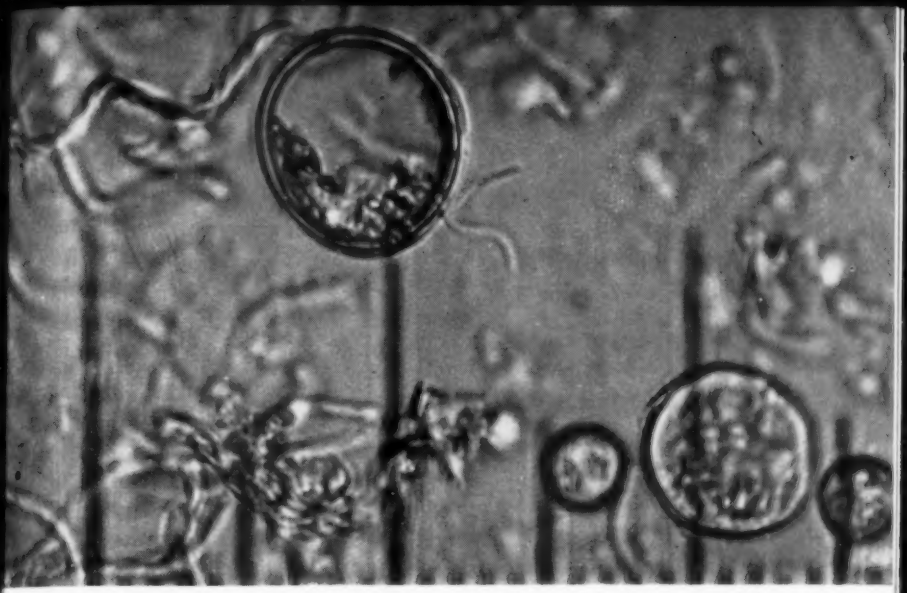
several enzyme systems with such varied activities as the breakdown and synthesis of proteins, and intracellular oxygen transfer. It is reasonable to suppose that this material might be liberated by the tissue breakdown which follows the death of living tissues.

The tentacles, when they are examined with a hand lens, are seen to be beaded throughout their lengths. Higher power of the compound microscope reveals that these beads are, in fact, "batteries," each containing hundreds of tiny stinging cells, whose normal function is to capture planktonic organisms and small fish which serve *Physalia* for food. The biologist calls them nematocysts.

The stinging cells are of the same general order of size as the red blood cells of man and therefore, of course, they are invisible to the naked eye. Fluid-filled bladder-like structures, they contain a hollow coiled tube. When the nematocyst is properly stimulated by contact with a suitable prey organism, the inner tube is everted forcibly. The reaction here resembles that of the finger of an inside-out rubber glove when it is blown out. Eversion of the inner tubule exposes its armor of barbs and spikes, so that the entire structure now resembles a harpoon and the rope which connects it to its identifying buoy.

Penetrates Surgical Glove!

The thread-like tubule may be twenty to fifty times as long as the diameter of the stinging cell. The in-



THIS IS WHAT HAPPENS *when the Portuguese man-of-war fishes! Stimulated by contact with a prey organism, the inner tube of each cell is everted forcibly, exposing its armor of barbs and spikes. This harpoon-like tubule may be twenty to fifty times as long as the diameter of the stinging cell. From a tiny opening at its outer end it injects poison directly into the prey organism or into the skin of an unwary human. (Charles E. Lane)*

dividual tube is hollow and its outer end is pierced by a tiny opening through which the poisonous fluid contents of the bladder may be injected directly into the prey organism, or into the skin of the unwary human who may become involved with the animal. This mechanism is so strong that it is capable of penetrating an ordinary surgical glove, as those working with it in the laboratory have found through painful experience.

One Thousand Deaths in a Thimble

Recent work in The Marine Laboratory shows that the fluid content of the nematocyst—the toxin—is an exceedingly poisonous protein substance. It is a neurotoxin. In other words, it effects the nervous system. But it does not dissolve the red corpuscles of the blood in the way that hemolytic snake venoms do.

When injected into mice, the lethal dose is approximately 0.037 ml per kilo of mouse. Since the test mice weigh only about twenty grams, it is clear that the amount of this material required to produce almost instant death in a single mouse is exceedingly small indeed. In fact, one thimbleful of the fluid is sufficient to kill well over one thousand mice.

The poison of the man-of-war is in the same range of total toxicity as crude cobra venom. It is fortunate that the Man of War is incapable of injecting a dose of venom into man equal in volume to that introduced by the bite of the snake—else *Physalia*

would surely eliminate ocean bathing along some of the best tropical beaches during the busy winter tourist season.

Can Sting Even in Dry State

The Marine Laboratory's research has been concerned with the effects of pure toxin. Before this could be prepared, it was essential to develop methods for the separation of pure undischarged and still-reactive stinging cells from tentacle tissue. Eventually a means of doing this was worked out. But, even so, one gallon of fishing tentacles is required to produce about 50 grams or about 1½ ounces of pure nematocysts. These retain their capacity to discharge and to produce typical effects for weeks, even in the dry state.

This conclusion was forced on us when nematocysts, or stinging cells, that had been permitted to dry on laboratory forceps or laboratory clothing, discharged days or weeks later, and produced their painful effects on laboratory personnel.

Work with the purified toxin in the laboratory shows that it is surprisingly labile or chemically unstable. Thus it is inactivated by warming to 60° C; by exposure to acids and alkalies and to organic solvents such as alcohol, ether, acetone and the like. It withstands freezing and will remain active for at least a year when it is stored in the frozen state.

Effects of Other Tests

It may be freeze-dried under vacuum with no appreciable drop in virulence, but drying at atmospheric pressure and slightly elevated temperature always inactivates the toxin.

Among laboratory animals subjected to injections of the toxin have been fiddler crabs, fish, frogs, mice and rabbits. For certain analyses, the toxin was added to the perfusion fluid bathing the isolated heart of the clam.

Dramatic Reactions

In the fiddler crab, the response to the toxic injections is dramatic and predictable. When the needle is withdrawn and the crab returned to its container, it makes a few quick running steps, then stops abruptly as it apparently suffers a general contracture of the flexor muscles of the walking legs. As a result of this, the crab appears to rise slowly to its tip toes. It remains paralyzed in this position during the gradual relaxation which terminates in death within minutes.

Fishes suffer disturbance of equilibrium, muscular spasm, local changes in color, and die within a short time. Frogs exhibit equilibrium changes, muscular spasms due to massive discharge from the central nervous system, respiratory arrest and death. In mice the response varies somewhat with dosage, but the basic effects here seem to be due also to the involvement of neural centers which control breathing and voluntary muscles. The mouse becomes acutely ill and may die in seconds after intravenous injection of toxin.

Clues for Treatment

These observations provide some clues for the rational treatment of a human being who has been the unfortunate victim of contact with the tentacles of *Physalia*. Of first importance is the removal of the adherent—and still dangerous—tentacles. On the

beach this may be done by scrubbing the afflicted area vigorously with sand and water.

Then it is essential that the undischarged nematocysts still present in the area be inactivated as promptly as possible. This may be done by local application of rubbing-alcohol, gasoline, kerosene, or other organic liquid which may be at hand.

These measures will insure against aggravation of the severity of the attack. They probably will do little to alleviate the effects of the toxin which has already been absorbed. Further treatment should be under the direction of a physician, who will prescribe suitable measures to correct symptoms of shock, and the *malaise* associated with a severe attack.

New Era for Marine Sciences?

A REPORT was recently made public which may exert a very considerable influence upon the future development of marine sciences. In fact it may well mark the beginning of a new phase in the history of marine biology and oceanography. This is the report of the Committee on Oceanography of the National Research Council, which was released on February 16th.

Oceanography has been neglected in comparison with other branches of scientific endeavor and it has become apparent to those concerned that this neglect could place the United States in a precarious position from the points of view both of science and technology and also of military preparedness. *Sea Frontiers* has drawn attention to this in a number of articles and editorials and is happy to report that a growing awareness on the part of a growing number of people has resulted, if not in immediate concrete action, at least in an authoritative report that will command the serious consideration of government and legislature.

The report offers recommendations for a minimum program of cooperative research and government support. Anything less than these recommendations would jeopardize the position of the U. S. A. in this field and accentuate military dangers.

The committee suggests that the government adopt a ten-year plan involving the replacement of the existing worn-out and makeshift research vessels now in use, the improvement of shore laboratories, an increase in graduate training programs for marine scientists and the development of new devices, instruments and such special facilities as research submarines. Altogether the plan involves additional expenditures of over $600 million during the next ten years. This is trivial compared to expenditures on rockets and space vehicles but is in some ways more important, when one considers that the single greatest threat to security today is submarine warfare. More detailed accounts of this lengthy report will appear in future issues of *Sea Frontiers*.

Oceanography in Cuba

By JOSE A. SUAREZ-CAABRO
University of Villanueva, Marianao, Cuba

PERHAPS THE MOST distinctive aspect of oceanographic work at the University of Villanueva is that it is all done with borrowed boats. The Marine Laboratory fortunately has been able to obtain the whole-hearted cooperation of the Cuban fishing industry, whose vessels are chartered when special off-shore investigations must be made.

This has certain advantages, over and above saving the heavy overhead and maintenance costs of operating permanent research ships. The crews of the chartered boats are quite familiar with Cuban waters and the Cuban fishing industry, and the vessels themselves can easily be adapted to marine research work. Scientists of the Laboratory carry their own equipment on board, rig it with the assistance of the crew, and return it to the Laboratory when the charter voyage is completed.

Youngster Among Marine Laboratories

Most people are surprised to learn that Cuba has its own Marine Laboratory. This is understandable because the institution has only just completed two full years of operation. The Catholic University of Santo Tomás de Villanueva, to use the full name of the parent organization, was not founded until 1946, when it was set up as a private educational institution by the North American Augustine monks.

In January, 1957, a Laboratory of Marine Biology was established at Villanueva, as a division of the Department of Research of its Faculty of Science. Its function is to contribute to the scientific study of the Cuban seas.

Site and Facilities

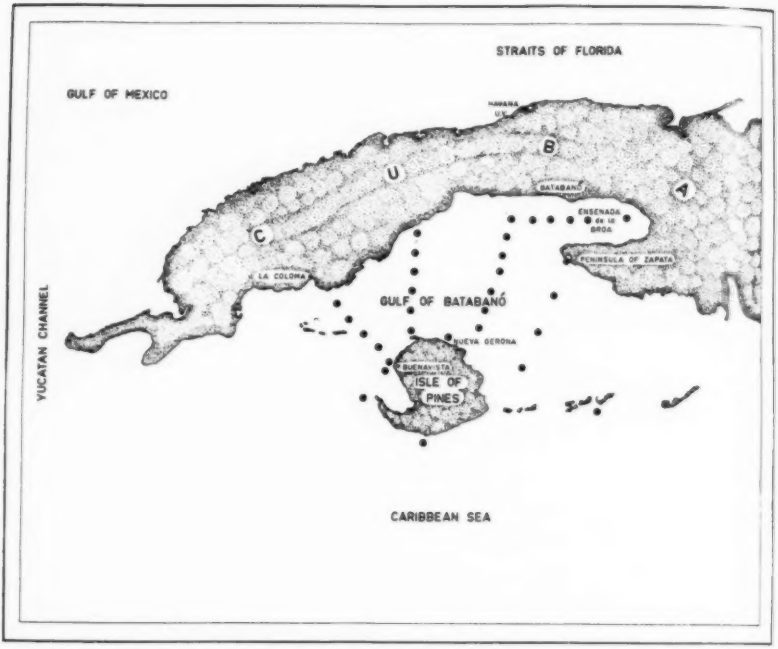
The Laboratory has its offices and equipment in the Tarafa Building, on the University campus, a short distance from the coast at Marianao, a western suburb of Habana. The location is a good one for our work. Nearby are found both rocky and sandy shores, and bordering waters of moderate depth, also many small coves or harbors. These conditions are ideal for underwater scientific investigations, and also for the enjoyment of water sports, which are gaining in popularity along the northwest coast of Cuba.

In this region numerous small rivers and *arroyos* empty into the sea, forming marshy areas, covered with mangroves. The entire littoral is rich in marine flora and fauna, including that of the coral reef. Opposite the Laboratory, the coastal shelf descends quite abruptly. Consequently, pelagic or deep-water game fishes can be found very near the coast, and specimens obtained when needed.

Cuba's Marine Laboratory, in fact, has a privileged position for effective marine research in tropical waters because it faces the birthplace of the Gulf Stream in the Gulf of Mexico, and is within a short air or boat journey of the Caribbean Sea, and the waters adjacent to the West Indian islands and the Bahamas. This miniature world of water contains thousands of varieties of marine flora and fauna about which little is known.

The Laboratory itself has sufficient space within the Science Building for office, museum, library, stockroom, etc. It makes full use of the cooperation afforded by the various University departments of chemistry, physics, pharmacy, etc., particularly where their work is applied to the sea. These departments also provide certain

UNIQUE FEATURE OF OCEANOGRAPHIC WORK *at the University of Villanueva is that it is all carried out in chartered boats. This has certain advantages, in addition to saving heavy overhead and maintenance costs. The crews are already familiar with Cuban waters, and with the fishing industry, and they can easily adapt their ships to marine research work. (Marine Laboratory, University of Villanueva)*



THE MARINE LABORATORY *of the University of Villanueva faces the head waters of the Gulf Stream near the city of Havana, an ideal place for the study of oceanic life and currents. However, its early investigations have been in the area of the Gulf of Batabanó, and the waters around the Isle of Pines. (Marine Laboratory, University of Villanueva)*

equipment and apparatus, both for investigative work ashore and at sea.

While the Laboratory has no facilities for accommodating visitors, nearby hotels offer a considerable discount to scientists and others who wish to visit or consult with the Laboratory.

Initial Investigations

The first oceanic investigations undertaken by the Cuban Marine Laboratory began in January, 1957, and extended to August, 1958. In this time a preliminary study was made of salinity, temperature and plankton of the coastal waters of the Isle of Pines, in the Gulf of Batabanó, south of the Province of Habana.

Each month the scientists of the Laboratory flew by plane from Habana to Nueva Gerona, Isle of Pines, and sometimes from there went by boats provided by the Navy. At other times they used chartered ships to reach specific stations to the north, east and southeast of the island.

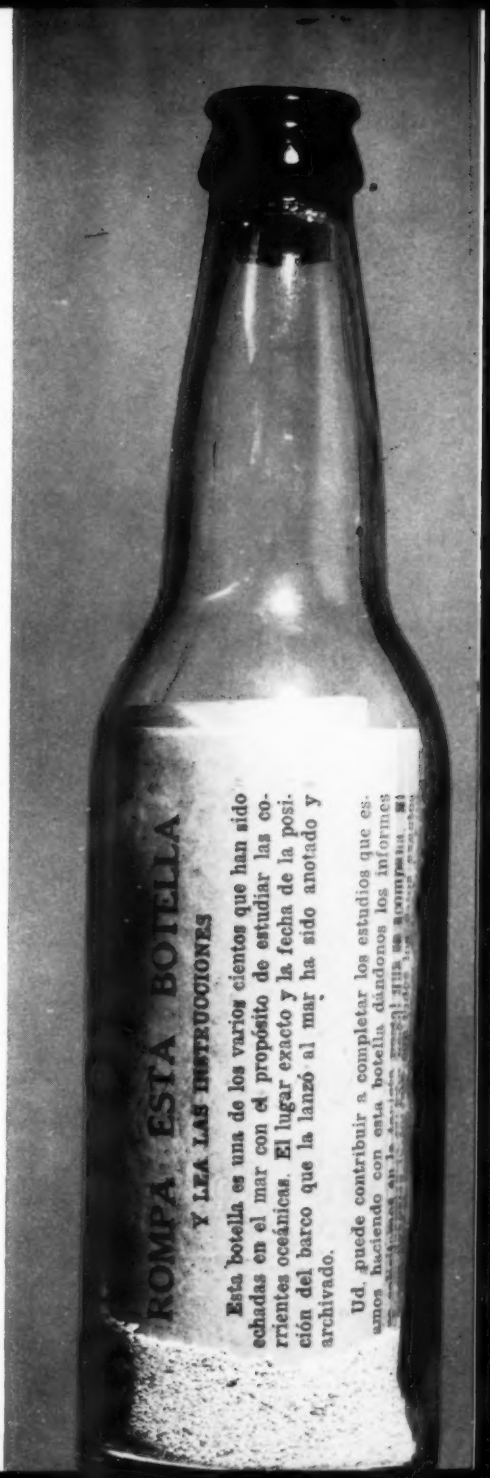
At the same time, notes were made of the meteorological data of the region, supplied by the Cuban Naval Observatory.

The material collected on these trips was taken back to the Laboratory and studied by scientists working there. Temperature, salinity and rainfall data were tabulated and compared, observing the monthly variations. Plankton volume was determined, and the zooplankton organisms likewise identified. In phytoplankton, the principal components were isolated.

These systematic studies were aided by the cooperation of several foreign laboratories, such as the Marine Laboratory, University of Miami; Woods Hole Oceanographic Institution; Bermuda Biological Station, and the U. S. Fish and Wildlife Service, whose specialists helped us in the difficult task of verifying many of the species. The identification of phytoplankton was kindly made possible by Sr. F. C. Müller-Melchers, of Montevideo, Uruguay.

Work in the Gulf of Batabano

Between December, 1957 and July, 1958 three oceanic cruises were made in order to carry out a more extensive study of the plankton of the Gulf of Batabanó. Altogether 29 stations were occupied, each about six miles apart. Again water samples were taken to determine salinity and oxygen concentration, at the surface, at the middle depths, and at the bottom. Likewise temperatures were taken


ROMPA ESTA BOTELLA
Y LEA LAS INSTRUCCIONES
Esta botella es una de los varios cientos que han sido echadas en el mar con el propósito de estudiar las corrientes oceánicas. El lugar exacto y la fecha de la posición del barco que la lanzó al mar ha sido anotado y archivado.
Ud. puede contribuir a completar los estudios que estamos haciendo con esta botella dándonos los informes

BOTTLE WITH A PURPOSE. *In order to study the currents in the Gulf of Batabanó, more than two hundred of these sealed drift bottles were thrown into the sea. In less than a year about 20 per cent of them were returned. Principal finding: a surface current in the Gulf, from east to west. (Marine Laboratory, University of Villanueva)*

WHILE THE UNIVERSITY OF VILLANUEVA *faces one of the beautiful palm-shaded boulevards of Marianao, Havana suburb, it is not far from the sea. At the right is the Tarafa Building, where the Marine Laboratory has its offices and equipment. Next to it is the Hickey building, and finally the Capilla. (Marine Laboratory, University of Villanueva)*

with reversible thermometers, and light penetration with Secchi discs. At the same time meteorological data were noted.

On each cruise the ship left the port of La Coloma, on the southwest coast of Cuba, travelling to Punta Buenavista, Isle of Pines. Then it followed the north coast of the island and continued the survey to the north, occupying stations in a direct line to the mouth of the Bay of Broa, thence into the Bay. The final series of stations was established between the Bay of Matahambre, on the Peninsula of Zapata and the east coast of the Isle of Pines (see map, page 16).

Although weather conditions during two of the cruises were quite adverse, with continuous head seas and strong winds, the work was completed in an orderly fashion and we were able to obtain all of the desired information.

This experience showed that it was possible to use oceanographic equipment on board ships only temporarily adapted for such work. This has partially reduced the difficulties which first appear when marine laboratories are formed and the extraordinary high costs of maintenance of their ships and use follows.

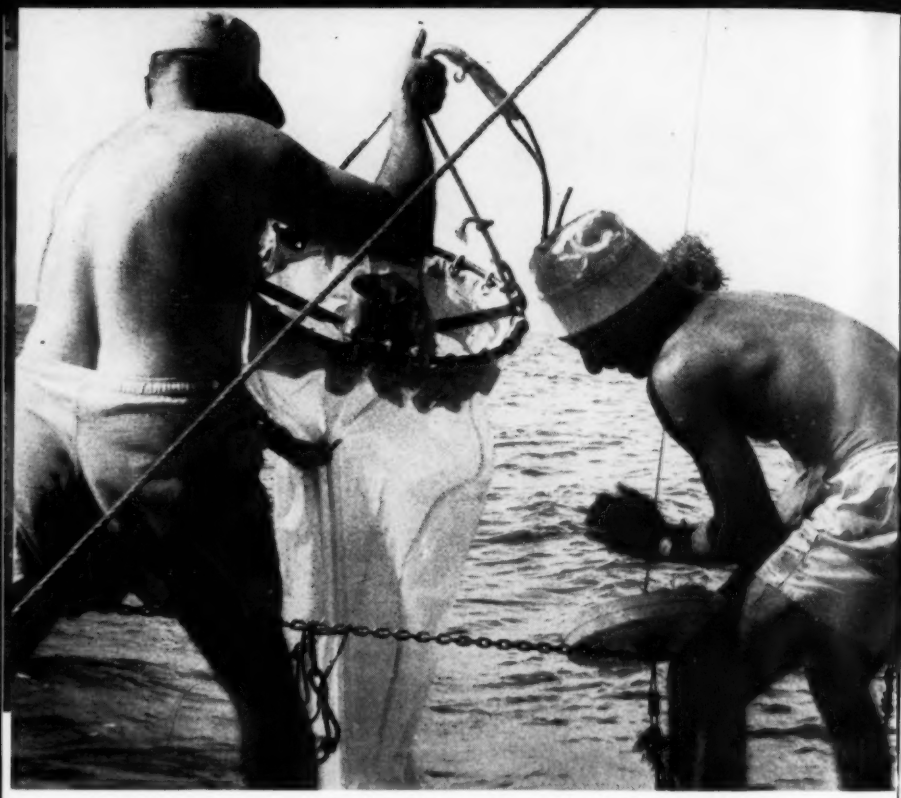
The ships employed under charter

were the shrimp boat type, between 35 to 40 feet long. The Nansen bottle holder was portably designed to conform to the facilities which each ship offered. A winch was used upon a wooden base, which was secured with bolts to the deck of the ship. The work was carried out always on the stern, where it is easier to load and unload equipment.

One of the operations of greatest interest to the staff was the utilization, for the first time in Cuba, of drift bottles to determine the direction of surface currents. During three cruises, a total of 210 bottles was dropped. In less than a year about 20 per cent of them have been returned. The principal finding: a surface current in the Gulf of Batabanó, from east to west.

Along with oceanographic field

NANSEN BOTTLE SAMPLING *is routine marine research work, but it yields valuable data needed by oceanographers and marine biologists. Here the author prepares to lower equipment that will secure temperature, salinity and oxygen-content information in Cuban waters that have not previously been studied. (Marine Laboratory, University of Villanueva)*



THREE OCEANIC CRUISES *have been made to the Gulf of Batabanó to carry out extensive studies of plankton, the food of the sea. Altogether 29 stations were occupied, each about six miles apart. In addition to net hauls, sunlight penetration was determined with Secchi discs. Experience proved that it was possible to use many kinds of oceanographic equipment on board chartered ships only temporarily adapted for such work. (Marine Laboratory, University of Villanueva)*

work, the Laboratory personnel completed studies of various organisms and of the general ecology of the region. They have already published six monographs and a report which contains some results of the investigations accomplished, also information on the projects and objectives of the institution.

Check List of Cuban Fishes

Moreover, the nucleus of a specialized library on oceanography has been set up and is being steadily enlarged through the exchange of publications from similar laboratories and institutions throughout the world, thanks to the help of the general library of the University of Villanueva.

Recently the laboratory published a check list of Cuban fishes, comprising 875 species, arranged according to zoological classification and adapted alphabetically by genera and species in each family.

The listing contains the Cuban, North American and principal West

Indies common names; geographical distribution; and an index of scientific names and of common names.

Museum of Marine Zoology

In addition to these investigations, the Laboratory has used University facilities in order that students of the zoology course in the faculty of pharmacy could carry out, in addition to their regular courses, studies on specific groups of mammals. These students are also collaborating in the development of a Museum of Marine Zoology at the Laboratory, making explorations for the purpose of obtaining specimens and learning the ecology at first hand.

The scientific personnel of the Laboratory has also contributed to the development and greater utilization of Cuba's marine resources, and has attended public meetings, as well as advised various fishing industries on this subject.

What Is Ahead?

In spite of the high cost of oceanographic investigations, the University has taken the first important step forward in creating this Laboratory of Marine Biology in the Faculty of Sciences, meeting the initial cost of purchasing necessary equipment and paying the wages of a staff capable of doing research in association with teaching duties. A minimum plan of field work in the Gulf of Batabanó has been drawn up. The University has already received some financial help from friends who, interested in these studies and knowing their importance, have decided to cooperate with the Laboratory.

The Laboratory has also some long range plans, including investigations of the identity and natural relationship of life among the Cuban corals, organic productivity of the sea by the carbon-14 method, systematics and ecology of the sponges, and biology of the economically important fishes.

It is believed at the Laboratory and the University of Villanueva that the oceanographic studies now being carried out, and those planned for the future by Cuban scientists, will serve as a basis for greater use of the boundless riches which the sea contains and which will eventually bring much economic benefit not only to Cuba but to mankind in general.

FOLLOWING TRIPS AT SEA, *the Marine Laboratory staff studies and identifies fish collected. Oceanic waters near Cuba contain thousands of varieties of marine flora and fauna about which very little is known. The first field trips for the Laboratory scientists began in January, 1957, and recently the staff published a check list of Cuban fishes, comprising 875 species. (Marine Laboratory, University of Villanueva)*

WHEN YOU SEE THIS HOUR-GLASS *formation at low tide, limnoria have been at their insidious work. Commonly called "gribbles," limnoria are tiny shrimp-like creatures which frequently concentrate their attacks between low and half-tide levels. They dig a network of shallow tunnels just under the surface of the wood, which washes away, layer by layer, until finally the piling is completely severed and structurally useless. (Department of Defense photo)*

Hidden Enemy in Our Harbors

by SIGMUND MILLER

AT ABOUT the turn of this century, many large and valuable waterfront structures were built along the northeastern shores of San Francisco Bay. The Mare Island Navy Yard, along the upper part of the bay, was the most prominent installation. This area was fed by fresh water streams, so that destructive marine borers were unable to live in the relatively fresh water.

But prolonged up-country dry spells decreased the fresh water supply for a few seasons, and the marine borers began to move in. Within the next few years, practically every wooden structure—piers, docks, bulkheads—in that part of the bay was destroyed.

2,000-Year-Old Pest

Marine borers have been known to exist as far back as the time of ancient Greece—"For as the ship by hidden shipworm spoil'd . . ." Publius Ovidius (43 B.C.—17 A.D.) Is it possible that man's progress has been so slow that he cannot cope with a pest which he has known for more than 2000 years? Actually, some fairly good methods for preserving marine pilings have evolved, but not until the disastrous and expensive occurrence at Mare Island did this country fully recognize the need for basic information about marine borers and methods for their control. Science now realizes that every biological fact uncovered about these creatures may be of enormous economic importance, because it might suggest some method of combating them.

Shipworm Not a Worm!

Teredo, the most widespread and familiar of the marine borers, is still popularly called a "shipworm." Although it has the appearance of a worm when pulled from its burrow in wood, teredo is biologically related to the clam and oyster. It begins its life as a tiny larva, capable of swimming for only short distances, and at the mercy of currents and tides.

At birth, the larvae are provided with a self-contained food supply, adequate to last a few days. If they manage to elude larger predatory animals they will survive, provided they encounter a suitable permanent homesite before the internal food reserve runs out. The animal begins to bore into the wood immediately after settling. From this time on, it *can never again leave its burrow.*

Strange Direction Sense

Covering the head of the teredo are a pair of hard, oval, rasp-like shells which the animal rotates back and forth to dig its cylindrical burrow. As the teredo matures, the cutting shells grow, and the diameter of the burrow increases. Soon after it has dug beneath the surface of the wood, the teredo usually turns until its burrow is aligned with the grain. It then travels in a straight line unless its path is barred by some obstruction, such

BUSINESS END OF A SHIPWORM. *Actually the shipworm, or teredo, is not a worm at all but biologically is related to the clam and oyster. A pair of hard, rasp-like shells cover its head. As the animal rotates back and forth they aid in digging a cylindrical burrow in pilings, docks, bulkheads, or any other timber it finds in the sea. (Marine Laboratory, University of Miami)*

as a knot or crack in the wood, a nail, or another shipworm's burrow. By some strange mechanism, it is able to sense such obstructions, and changes the direction of its burrowing in time to avoid it.

If a lack of space forces the shipworm to dig through the outer surface of the wood, it dies almost immediately. But the teredo has another trick which helps it to survive. When the young animal finds itself in a piece of wood which is too narrow to allow normal growth of the cutting shells, the shells grow only until the diameter of the burrow is slightly smaller than the thickness of the wood. After this, the shipworm continues to increase in length, but its burrow does not increase in diameter unless it reaches thicker areas of wood.

Almost Invisible Opening

The small opening which the larva makes in the surface of the wood never enlarges, and the tail of the animal always remains at this hole, so that the shipworm fills its burrow. A piece of wood can be completely honeycombed with shipworm burrows, yet only some tiny holes will show on the surface. A pair of tubular siphons at the teredo's tail pumps fresh sea water through its body.

One siphon draws in oxygen-rich water, containing microscopic organisms, to supplement its diet of wood. Digested wood particles and other waste products are pumped out

through the other siphon. If an enemy approaches its burrow or if the water quality becomes poor for some reason, the teredo can withdraw its siphons and make the burrow entrance watertight by plugging it with the two prongs of its tail, which are called pallets.

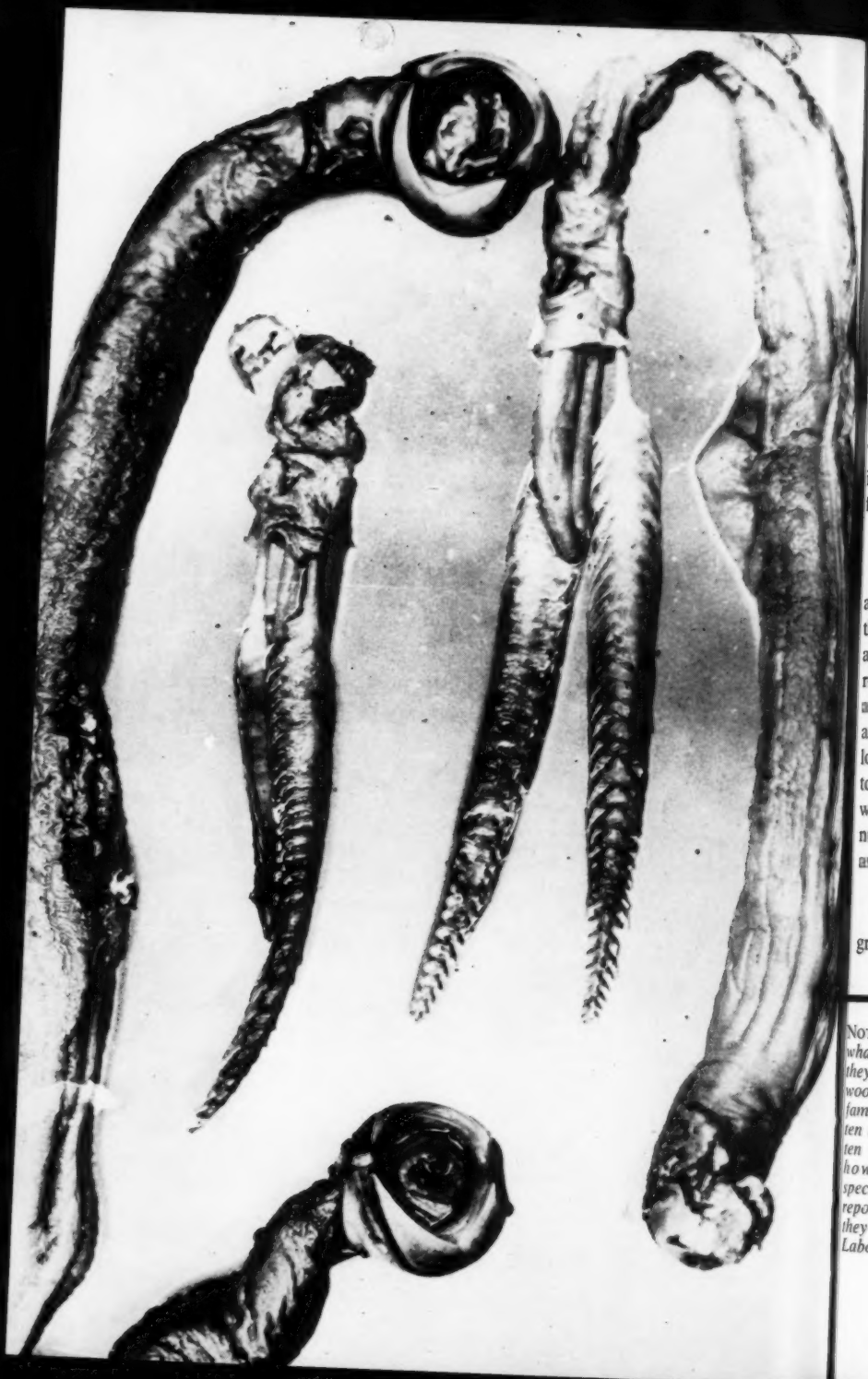
Reserve Food Supply

While maturing, the teredo builds up a reserve food supply in its body. If conditions at the burrow's entrance are unfavorable, the teredo seals the entrance with its pallets, *and can survive on its reserve supply for weeks.* Is it so surprising that such hardy pests have been so difficult to defeat?

As it digs its burrow, the teredo lines the walls of the cavity with a material similar in nature to an eggshell. By pumping its soft body full of water and thus pressing it against this hard lining, the animal gets enough leverage to rasp away deeper into the wood with its shells.

There are a great many biological species of the teredo family (called Teredinidae). The method they use to destroy wood is the same, but some aspects of their behavior, average size and life spans differ. The most familiar members of the Teredinidae live for from two to ten months, during which they attain a length of ten or twelve inches and a diameter of about one-quarter inch. Some found

THE TAIL OF A SHIPWORM *is a marvelous mechanism. While the tiny exterior hole made in the wood by the larva of the shipworm never becomes large, it is just sufficient to allow protrusion of a pair of syphons, which pumps fresh sea water through its body. One syphon draws in the organisms the teredo needs to supplement its diet of wood; the other pumps out waste products, such as digested wood particles and deoxygenated water. (Department of Defense)*



in tropical waters reach three feet and others as long as six feet have been reported, but fortunately these are quite scarce.

The Biter Bitten

Teredo may have been created only for the purpose of destruction of wood, but some natives of the Fiji Islands and Thailand think otherwise. They consider teredo to be a great delicacy when extracted live from the burrow and eaten "on the halfshell." They even plant pieces of soft wood in the sea to make a kind of shipworm farm.

Pholads Resemble Clams or Oysters

Another group of molluscan borers are the pholads, which are shorter than teredo, and more clam-like in appearance. Some pholads can burrow into soft rock and weak concrete, as well as into wood. Their burrows are never more than three inches long, and the entrance is large enough to be easily detected. Luckily, the wood-destroying pholads are not as numerous nor as widely distributed as teredo.

Crustacean Brothers-in-Crime

The crustacean wood borers are a group which are as destructive as the molluscs, but not so subtle. These are small, somewhat shrimp-like creatures. For tearing away at wood fibers, crustacean borers use their strong, claw-like jaws, called mandibles. *Limnoria* cause the most destruction, and are responsible for the familiar hour-glass shape of marine piling which they have attacked.

Limnoria, commonly called the "gribble," grows only to about the size of a grain of rice. It concentrates its attack between low tide and half-tide levels. The animals dig a network of shallow tunnels just beneath the surface of the wood. When the surface layer has been weakened by their excavations it breaks away and the gribbles begin undermining another layer. Within a year or two they can cut through a one-foot diameter piling between tide marks, leaving the rest of the piling perfectly sound but structurally useless.

Can Leave Their Burrows

Limnoria are able to move around freely in their burrows and can also leave the burrow in search of more wood. Since they are also fairly good swimmers, this means that infection can easily spread up and down a coastline. They are not nearly as prolific as teredo, but the mortality rate is much lower. The female gives birth to a few young at a time and these almost immediately begin gnawing on wood, right alongside the parents.

There are other wood-boring crustaceans which are far less destructive, however. *Sphaeroma* closely resembles the "pill bug" commonly found in damp earth under stones. It is frequently termed a "putty bug,"

NOT A VERY PLEASANT SIGHT, *but this is what shipworms really look like when they have been extracted from their woody burrows. Most members of the family Teredinidae live for from two to ten months, and attain a length of from ten to twelve inches. Tropical cousins, however, reach three feet, and rare specimens as long as six feet have been reported. In some parts of the world they are even used as food. (W. F. Clapp Laboratory)*

because of its appetite for caulking in the seams of boats.

Strange Legends

Practically nothing was known about the biology of the borers until the nineteenth century and this probably accounts for many of the interesting and, sometimes, fantastic stories which have originated as a result of their activities.

In a sixteenth century history of Scotland, a story is told which is undoubtedly linked to the legend of the barnacle goose (see *Sea Frontiers*, Vol. 3, No. 3, September, 1957). The author states, "When wood is exposed to the sea, many worms generate in it and finally develop into geese with wings and feathers."

In 1730, the coastal cities of Holland were threatened with floods because the oak piles used to support the dikes were repeatedly destroyed by marine borers, usually in only a few months. The predicament must have been caused by the same type of climatic conditions which later brought on the destruction of installations in San Francisco Bay, because in 1739 one commentator remarked, "But the Divine Clemency has already so far destroyed these pernicious Insects, which multiplied so prodigiously for eight or nine years past, that there is great room for Hope, that our Country will in a short time be entirely freed from them."

Greeks Had a Nail for It

The ancient Greeks and Romans devised at least one effective means of protecting their wooden marine structures. The practice of "scupper-nailing" or "filling" resulted from an observation that wood in the vicinity of a nail was not attacked by shipworms. Large-headed nails were driven close together into the surface of the wood to be protected.

When properly done, with the nailheads overlapping, complete protection from borers was provided until the nails corroded away. This tedious process was only practical in an economy in which the nails were worth more than the man who drove them.

Other Protective Methods

Near the end of the seventeenth century the labor-saving device of lead sheathing was adopted. A little later, the process of "Verhauderung" was devised. Cow's hair was stuffed between a ship's oak planking and an outer layer of expendable fir planking, "in order that the shipworm becomes entangled in it."

We now know that this method was effective because the teredo is unable to burrow across a void between two pieces of wood. Essentially the same process is used in construction of the "false keel" on many of today's wooden vessels. A layer of tar-impregnated felt is attached to the keel, and over this is fastened a replaceable false keel of less expensive wood.

ALTHOUGH A SHIPWORM *spends its entire life buried in timbers, it has no secrets the X-ray cannot disclose. Such photographs are of great value to marine biologists, who must know more of growth rate and other vital aspects of this sea pest before any effective control can be set up. To a surface inspection this plank would seem sound, but actually it has already lost most of its structural strength. (Marine Laboratory University of Miami)*

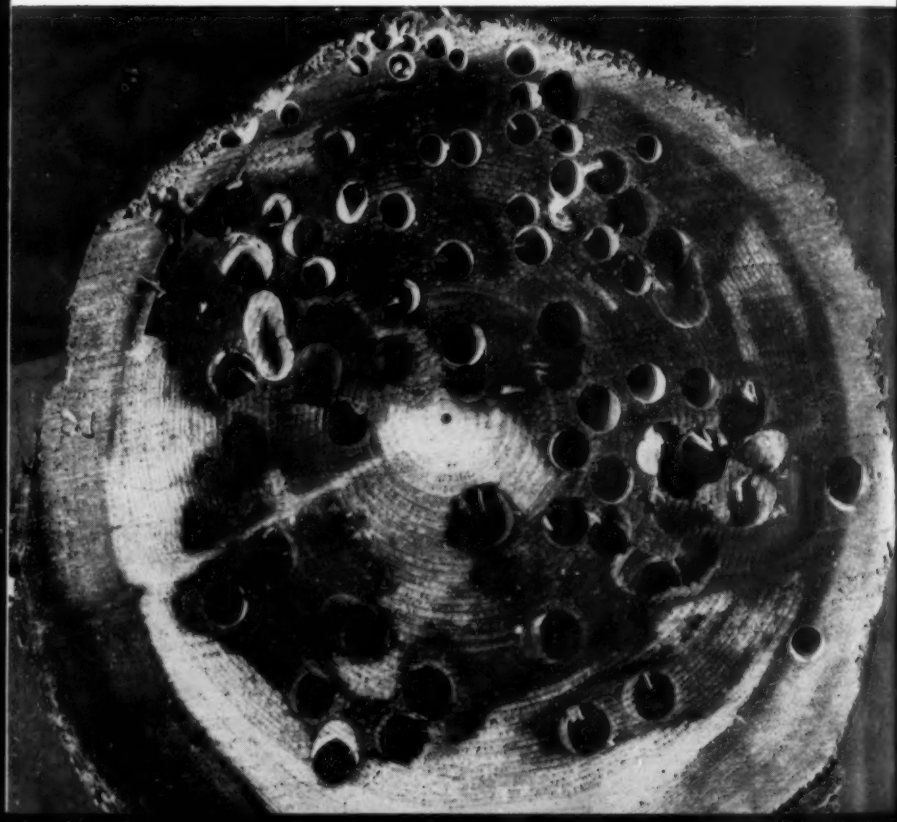
Shipworms can burrow into and destroy the false keel if its paint is scraped, but they are unable to cross the felt strip.

H.M.S. Alarm *Disaster*

The practice of lead sheathing was improved upon in the 18th century, when sheathing with copper was suggested. The copper not only protected the wood from borers, but was also an effective antifouling device for ships.

Unfortunately, one of the first attempts to use this process resulted in a catastrophe. In 1761, H.M.S. *Alarm* was fitted with copper sheathing covering the entire hull. The architects, knowing little about corrosion processes, unwisely specified that iron nails be used to fasten the plates to the hull. When the ship was launched, galvanic action between the two metals caused the nails to corrode rapidly, and the sheathing fell away, unnoticed. The vessel sank after a few months of intense borer attack.

A suitable change was made in the process after inspection of the salvaged hull. The new method enjoyed widespread popularity until the cost of copper increased, and some "en-



LOOKS LIKE CHEESE, *but it is really a cross section of one of the dock pilings at the U. S. Navy Base, Adak, Alaska, riddled by teredo, or shipworms. Defense installations have been damaged to the extent of millions of dollars annually by this enemy that bores from within. (U. S. Navy Photo)*

terprising" individuals began to make a comfortable living on the copper pilfered from the hulls of moored vessels on moonless nights!

Chemical Preservatives

Methods suggested for marine borer protection during the past century would fill several volumes. Most of these have been mechanical devices, but, since the industrial revolution, chemical preservatives have been used most extensively. Creosote, which was once considered to be a waste by-product in the process of coke production, is now the most popular preservative for preventing marine borer damage. It is not a single chemical, but is actually a mixture of a large number of chemical compounds, several of which are known to be poisonous to insects, molds, fungi and bacteria. To be effective it is injected into the wooden piling under steam heat and pressure, until the soft outer "sapwood" portion of the piling is thoroughly saturated.

Two Main Problems

Creosote-treated wood has many times the usable service life of untreated wood, but this varies, depending upon the location and the type of borers which predominates in the area. It may give more than fifty years of service in some northern harbors, but in the tropics it may be useful for only five to ten years.

Economically speaking, the battle against marine borers resolves itself into two main problems: how to preserve existing wooden structures, and how to make new structures more borer-proof. Shipworms in existing installations are not easily killed by adding poisonous chemicals to the water. As mentioned previously, they can isolate themselves from the surrounding water for weeks.

In the harbor at Sydney, Australia, the type of wood used for piling is almost immune to attack by teredo, but is quickly damaged by *Limnoria*. Piling is protected by coating the inter-tidal zone with creosote once each year. A floating collar is placed around the pile, and the space between the pile and the collar is filled with creosote, which floats on the surface of the water.

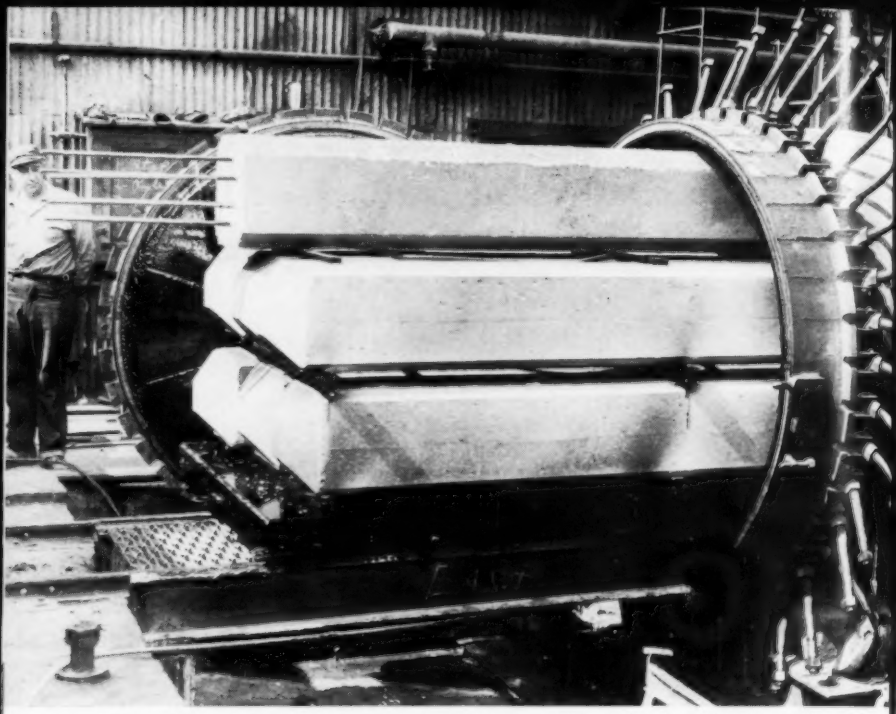
Saves $92,000 Annually

The collar is left on the pile for 24 hours, so that it traverses the intertidal zone four times, soaking the wood with creosote each time it passes. Authorities in Sydney estimate that this method has reduced attacks, with a savings of $92,000 per year. The method might also prolong the life of *creosoted* piling in areas where these are rapidly damaged by *Limnoria*.

At present, it appears that the most reasonable method for preserving structures which are being damaged by borers is to cover the surface of the wood with a material which can resist penetration. It has been proved that borers will not penetrate even a thin film of paint to gain access to wood, but because it is susceptible to mechanical damage from ships and floating debris, paint is good only as a temporary deterrent to borer attack.

High Cost a Factor

Several other types of coatings and casings are being used successfully



STEEL-REINFORCED CONCRETE RESISTS MARINE BORERS, *but is still vulnerable to the corrosive action of sea water, and is more costly than timber. Thermal expansion and contraction of the concrete develops tiny cracks, allowing sea water to seep in and corrode the imbedded steel. The illustration shows reinforced concrete piles about to be waterproofed by pressure impregnation with molten asphalt in a California treating plant. (Los Angeles Harbor Department)*

but not extensively, usually because of their high cost of application. The most widely-used encasing process involves jacketing the wooden pile with a thick layer of concrete. Split-cylinders of sheet metal are placed around the pile in short sections which, when coupled together, extend from the sand or mud bottom to above high tide level.

The cylinders are usually provided with spacers to keep them concentric to the pile. After the concrete is poured and has set, the forms are removed, or, if they are made of inexpensive material, are left in place.

Steel and Concrete Vulnerable, Too

The greatest problem facing marine architects and engineers today is that of deciding what kind of material to use for building new structures which must withstand the ravages of sea water for many years. Because of the difficulties which marine wood borers have caused in the past, the trend is towards the use of more steel and concrete in marine construction, in spite of their relatively high cost.

Even if the cost factor is excluded, however, these materials are not always satisfactory substitutes for wood in marine construction. Steel is sub-

ject to severe corrosion by sea water and salt spray. An electrical process called *cathodic protection* can be used to prevent corrosion of submerged steel, and frequent painting will protect the portions of structures above low tide level, but this type of maintenance is expensive.

Reinforced concrete is a very satisfactory substitute for wood in marine structures, but special techniques must be used to prevent premature failures. The chemical composition of the cement, the proportions of ingredients in the concrete and the thickness of concrete covering the reinforcing steel are critical factors.

New Concrete Treatments

Recently developed processes for pre-stressing, air entrainment and asphalt impregnation of concrete have made it possible to produce a concrete which is suitable for many applications in marine construction.

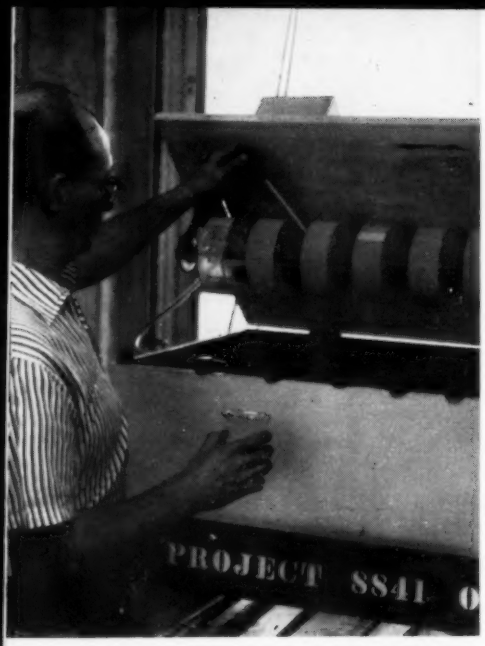
Nevertheless, wood could be the most desirable material if it were not attacked by marine borers. It is inexpensive, durable, strong and resilient, can be made fireproof at little expense, and abundant supplies are available. If a method could be developed for imparting permanent borer resistance to wood without detracting from its other desirable properties, an enormous savings in marine construction costs could be effected.

Goal of Science

Marine laboratories all over the world are searching for a chemical preservative process which will protect wood from marine borer attack for at least fifty years *in any location*. It is agreed that the ideal preservative should have the following properties:

It should be highly toxic to all types of marine borers; it should not injure the wood; it should be safe to handle; it should be insoluble in sea water, but sufficiently soluble in the

CROSS-SECTION OF ASPHALT-IMPREGNATED PILES *shows a surprising depth of penetration of the waterproofing agent. A special grade of porous concrete was used for the uniformly impregnated piles to the left. The life of concrete piles is extended many years by this process. (Los Angeles Harbor Department)*



SPEEDING UP THE TESTING PROCESSES. *Because scientists cannot wait out the long periods of time which would normally be required to determine whether certain wood treatments are effective against marine borers, machines bridge the time gap. Here the author shows how wood, treated with experimental preservatives and ground to sawdust, is leached in a bath of flowing sea water. Only a few days testing in such a device gives the equivalent of years of leaching, or the loss of preservative qualities which occurs in full-size piling. (Marine Laboratory, University of Miami)*

digestive fluids of the borers to produce an instantaneous lethal effect; it should have a preservative action against the microscopic organisms which cause wood to rot. For purposes of economy, it would be desirable to use water as a medium for carrying poisonous materials into the wood. Alternately, if some other carrier must be used, it would be desirable that it be volatile, so that it could easily be reclaimed.

Can Creosote be Improved?

The most desirable preservative would be one which, when impregnated into wood, would chemically combine with the wood itself to form a poisonous, insoluble material. Since creosote has already proved to be so effective in many locations, it may be possible to improve it sufficiently by the addition of other poisons.

The ideal wood preservative may already have been discovered! Laboratory tests have indicated that many organic poisons are lethal to marine borers in extremely small doses. Unfortunately the only dependable method for determining the durability of preservative-treated wood is to expose samples of it in many locations to subject it to all types of borers and climatic conditions. But, in this manner, it might be necessary to wait fifty years for the outcome of a successful test. For this reason, various methods have been devised to accelerate the "aging" of treated wood artificially, so that the permanence of preservatives can be determined in a period of months instead of years.

Borers Eat Sawdust Too

In one such process, wood treated with experimental preservatives is ground to sawdust, which is then leached for several days in a bath of flowing sea water. Because the particles of wood are so small, the short leaching treatment has the same effect as years of leaching of a full-size piling. Later, the leached sawdust is pressed into panels by the same process which is used commercially to make "particle board." These panels are then exposed to borer attack in

the sea, to learn to what extent the treated wood has retained its borer resistance.

Extensive research on marine borer control methods is being conducted at laboratories in the U. S. A. by Dr. T. R. Sweeney at the Naval Research Laboratory in Washington, Dr. H. Hochman at the Naval Engineering Laboratory in Port Hueneme, Calif., A. P. Richards at the Wm. F. Clapp Laboratories in Duxbury, Massachusetts, and Carrol Wakeman, of the Los Angeles Harbor Board, among others. Great Britain, Germany and New Zealand also have active research units. Their efforts may well help to shorten the battle.

Electric Trawl Fishing

A Dutch fishing trawler owner has reportedly developed a new method of electric trawl fishing. An electric cable replaces the tickler chain, which is usually attached to the mouth of the standard trawl net, and which, by scraping on the sea bottom, serves to scare fish into the net.

The cable produces an electric current in front of the trawl opening which not only scares fish into the net but also prevents them from leaving the net. In addition to increased catches, the new device serves to reduce the net load drawn by a trawler, since the electric cables do not touch the sea bottom.

See also: "A Shocking Way to Fish!" by C. P. Idyll, *Sea Frontiers*, Vol. 4, No. 2, May, 1958.

Three-Nation Cod Pact

In these days, when agreement between nations on almost any matter comes the hard way, it is refreshing to note that recently at San Sebastian, Spain, representatives of Spanish, French, and Portuguese cod interests quietly signed a pact that should find amicable solutions to certain basic problems that long have plagued the industry.

The agreement pledges boats of each country to give mutual aid to injured and sick fishermen, assistance in lifesaving, collision rights, etc., which result from the close-quarter methods of fishing traditionally employed by the fishermen of the three countries off the banks of Newfoundland, Labrador, Spitsbergen, and in the Barents Sea.

CHARTER BOATS HAVE GREATLY AIDED SCIENCE *by reporting data on tuna, sailfish, marlin, and other open sea fishes about which little is known. One of the most helpful has been Captain Eddie Moore, shown here at the controls of his cruiser* PANDA, *heading past South Bimini en route to the Gulf Stream and a day of big game angling. (Photo by Thornton)*

Busy Week for Men and Fishes

By ERL ROMAN

THE WEEK OF November 17th, 1958, was a busy one for many Foundation members and one in which fishes came in for intensive scrutiny. Some of the participants in meetings held at Miami Beach were at work disentangling the vexed problems of identity of the marlins and spearfishes of the world, while others devoted a full five days to scientific matters affecting the commercial fisheries. At the close of the week the Board of Trustees of the Foundation held its annual meeting.

Many creatures of the sea are comparative strangers, and not all of these dwell in the great depths. Among the more mysterious are the pelagic, or "blue water" fishes, which usually spend their lives far from shore, but often near the surface of the sea, where they are sought by scientists and game fishermen.

Spread to Remote Waters

Competitive game fishing is one of the younger competitive sports, dating back only to the first tournaments held at the start of the century in California, and later in the Bahamas, along the Atlantic seaboard of the United States, and in Nova Scotia.

Gradually its popularity has spread to other regions, including such remote waters as the Indian Ocean, the

west coast of South America, and Australia, as well as more accessible areas along the Pacific coast of North America, the West Indies, the Caribbean, and the Mediterranean.

As more and more anglers take up the sport, however, the need for accurate information about species and habits becomes imperative. How can "record catches" or "new types" be established if there be confusion about such simple matters as the common names of certain large fishes? There is still doubt, for instance, as to whether there are one or two blue marlins in the Eastern Pacific, and one of these was once called a silver marlin.

Meeting of Kindred Souls

Because everyone concerned has a common desire to untangle these and other mysteries concerning such important oceanic wanderers, the International Oceanographic Foundation has, for the past three years, sponsored an International Game Fish Conference.

This congenial meeting of big game anglers, fishing guides, charter boat owners, and marine scientists is usually held in November, in conjunction with the Gulf and Caribbean Fisheries Institute, so that those interested in other phases of oceanic life may attend both gatherings, and discuss matters of mutual interest. The first conference, in 1956, was held in Nassau, the Bahamas; those of 1957 and 1958, in Miami Beach, Florida.

Six Papers Presented

At the November, 1958, Game Fish Conference, held at the Barcelona Hotel, Miami Beach, six original papers, covering a broad field of fishing interest, were presented as follows:

"Biology of the Tarpon," by Dr. John E. Randall, Marine Laboratory, University of Miami; "Life History of the Great Barracuda," by Dr. Donald P. de Sylva, Bayside Laboratory, University of Delaware; "A Review of the Amberjacks of the Western Atlantic," by Mr. Frank J. Mather, III, Woods Hole Oceanographic Institution; "Marlin and Sail Fishing on the East Coast of South Africa," by Col. John K. Howard, Marine Laboratory, University of Miami; "Current Status of Marlins and Spearfishes," by Dr. C. Richard Robins, Marine Laboratory, University of Miami; "Foods of the Pelagic Fishes of Puerto Rico and the Bahama Islands," by Mr. Donald S. Erdman, of the Department of Agriculture and Commerce of Puerto Rico.

Rod and Reel Club Session

Following the presentation of the papers, the meeting adjourned for luncheon at the Rod and Reel Club of Miami Beach, on Hibiscus Island. The remainder of the afternoon, at the Club, was devoted to animated discussions, with a question-and-answer period, of the papers presented during the morning.

Most widely debated topic was the current status of marlins, spearfishes and amberjacks, all popular with sports fishermen. Actually the discussions picked up the general trend of two previous conferences, and some of the replies from the experts present could be considered "progress reports" on subjects of sustaining interest.

GATHERED IN THE INTEREST *of science and game fishing. At the doorway of Miami's famed Rod and Reel Club stand (left to right) Hon. Ross Leffler, Assistant Secretary of the Interior for Fish and Wildlife; Dr. Gilbert L. Voss, Research Associate Professor, The Marine Laboratory, University of Miami; John D. Simmons, former President of the Rod and Reel Club; Dr. C. Richard Robins, Research Assistant Professor, Marine Laboratory; and Dr. F. G. Walton Smith, director of The Marine Laboratory and Vice President, International Oceanographic Foundation. (E. John Long)*

At the recent Conference, however, more positive information was available on many pelagic or open-sea fishes as a result of research and other investigations conducted in recent months. For example, Erdman's report was the culmination of years of observation on pelagic fishes off Puerto Rico.

Two Marlin Names Eliminated

The marlins of the Atlantic Ocean, it was brought out, are the blue and the white, unchanged from common usage over many years. In the Pacific, however, the marlins have been limited to three kinds: striped, black, and Pacific blue. This eliminates the silver and the great Tahitian marlins formerly listed, doing away with considerable confusion for scientists and sports fishermen.

Scientists believe there may be two types of blue marlin in the Pacific Ocean and also in the Indian Ocean. However, the name, Pacific blue, may cover them as far as anglers and fishing guides are concerned.

Work on the vexed questions of the marlins is continuing through a special committee of experts convened by the Foundation. Dr. Richard Robins, one of the members of this committee, expects to visit Hawaii early in 1959 to obtain further first hand information on the Pacific species.

Mediterranean Spearfish?

As for the Mediterranean spearfish, so sparse is the information available on them that some scientists doubt reports of their existence, and express the opinion that they may have been confused with white marlin. Naturally,

scientific research on this problem will be pursued until it is determined exactly what fish it is.

Because space does not permit a full appraisal of the papers and the discussions of the Conference, the papers are being made available to those registered in mimeographed form.

I. O. F. Progress

Another meeting held during the same week was that of the Board of Trustees of the International Oceanographic Foundation, on November 21, under the chairmanship of Charles F. Johnson, president. A report on membership showed that it has more than doubled in 1958, and that income from memberships and special gifts has also greatly increased.

Dr. F. G. Walton Smith, vice-president and executive secretary, announced that the Foundation had donated approximately $13,000 to research institutions for the study of game fishes, marine sediments, and other oceanic problems, as well as continuing to publish *Sea Frontiers* and *Sea Secrets*.

An analysis of membership was given by F. May Smith, and a general report on editorial matters was presented by E. John Long, both of the staff of *Sea Frontiers*.

Eleventh Annual Institute

The eleventh annual Gulf and Caribbean Fisheries Institute, originated and sponsored by The Marine Laboratory of the University of Miami, held sessions at Miami Beach from November 17 through November 21. Meeting simultaneously with the Institute were the Shrimp Association of the Americas, Southeastern Fisheries Association, and the Atlantic States Marine Fisheries Commission.

Among the distinguished guests at these sessions were the Hon. Ross Leffler, Assistant Secretary of the Interior for Fish and Wildlife, and representatives of other governmental agencies concerned with fishing in many States and foreign countries. Newly discovered and better methods of fishing and merchandising of fishery products, locations and scope of present fish stocks, improvements in fishing craft and gear, and kindred matters were taken up during the meetings. Dr. C. P. Idyll, Marine Laboratory, University of Miami, was elected chairman.

The Bay's Most Abundant Fish

Chesapeake Bay teems with seafood, but its most abundant fish, the anchovy, is seldom caught, and if caught almost never eaten. Yet, when imported, it is a delicacy that commands premium prices. However, the anchovy is the favorite food of many species of fish, including the striped bass, most sought by Bay fishermen. So, indirectly, the anchovy plays an important sustaining role in the cycle of Chesapeake marine life.

Gold in Them Thar Waves!

By E. JOHN LONG

SCOOP UP A GLASS OF sea water and look at it. Unless it is clouded with local impurities and algae, not found in most of the 300,000,000 cubic miles of water that make up the world's oceans, the liquid in the glass will be clear, almost colorless.

Taste it, however, and you will know there is something more than water here. Incredible as it may seem, this little container of sea water holds traces of all the important elements known to man, including minerals many times heavier than water itself. This does not mean, of course, that the minerals are present in their solid state, too small to be seen by the naked eye. But they are here nevertheless in hundreds of variations of dissolved compounds or salts.

Take a Cubic Mile

Each cubic mile of sea water, for example, contains some eighteen million tons of magnesium, that most versatile light-weight metal, as well as large quantities of other chemical compounds embracing sodium, sulphur, calcium, potassium, bromine and chlorine, plus dissolved salts of the more familiar metals, such as gold, silver, aluminum, radium, nickel, iron, chromium, and even that rising star of the atomic age—uranium.

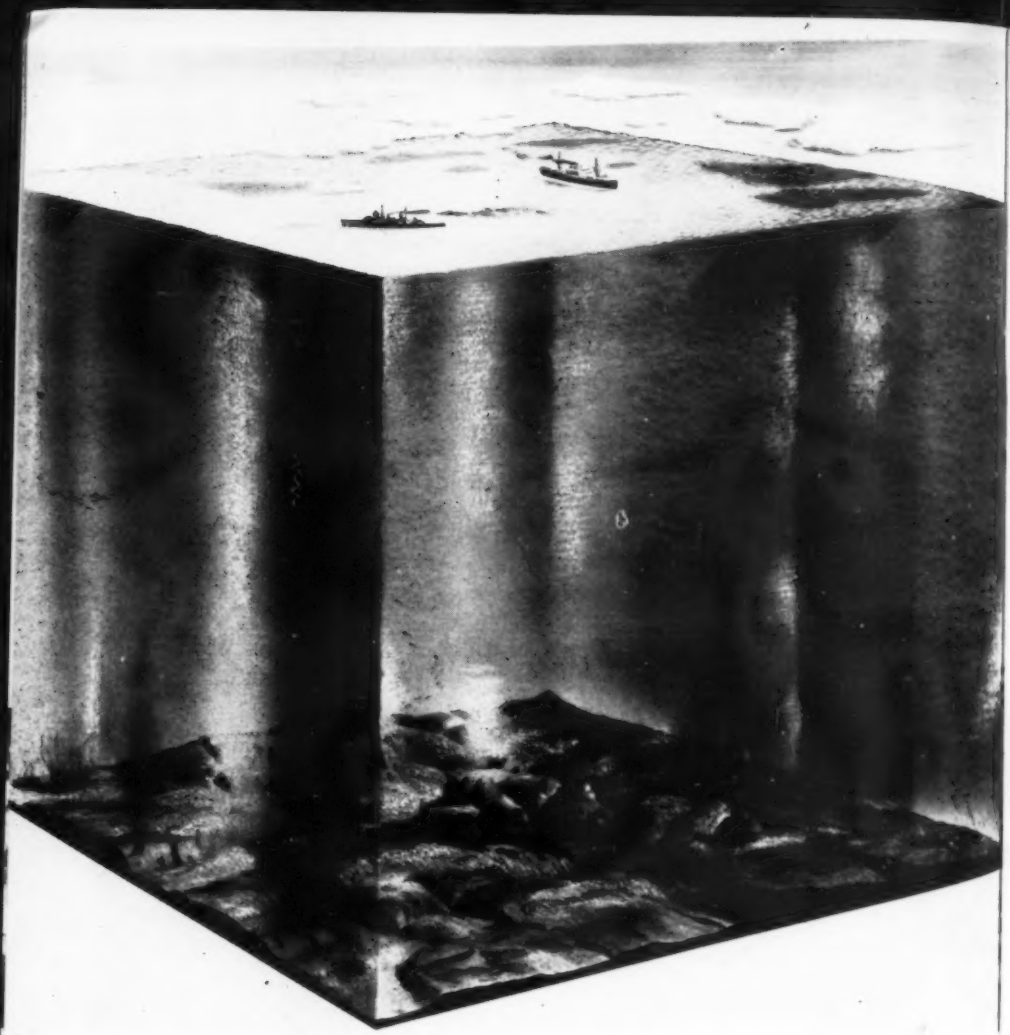
Does it seem strange to consider the ocean as a "mineral mine?" Scientists say it should not. Oceanic waters contain more minerals than have been mined by man in all history. For millions of years the processes of erosion and land drainage have brought a continuous flow of dissolved and corroded metals and elements from every part of the earth to the sea, to be absorbed and distributed in the water vastness that covers almost three-quarters of the earth.

Thus is continued an age-old, long range cycle, because many of our present land minerals are, in fact, derived from deposits of ancient seas which once covered all the continents. There seems to be no logical reason why man should not shortcut this cycle, by mining the seas, if he is able to do so.

Industry's Pressing Needs

As the world's population continues to grow at an ever accelerating pace today, and as man's need for minerals of all kinds expands, the prospect of exhausting many of the accessible land ores and metals is a very present and ominous one, caus-

SMOKE PLUMES *from the mineral mines of the future? That is how a chemist may well regard these sea waves, dashing themselves into spray against the stern and rockbound coast of Maine. Within each droplet are traces of all the important elements known to man, including minerals many times heavier than water itself. In fact, oceanic waters contain more minerals than have been mined by man in all history. They are not there in solid state, of course, but in hundreds of dissolved salts and compounds. (Charles E. Lane)*



ing grave concern among industrial and political leaders.

Land minerals are found generally in local concentrations which, once mined and used, are gone. Some of these are already in short supply, giving rise to stock-piling in the United States, during and since World War II. As the better, more concentrated ores become exhausted, too, use must be made of the lower grade remainders, which are more difficult and expensive to extract.

Frontier of the Chemist

Mining the vast resources of the sea for our economic welfare is not just a paper scheme nor a nebulous hope. On a modest but growing scale, it is an actuality today. In place of the mechanical engineer with his steam shovel, or the miner with his pick and shovel, however, "maritime mining"

CONSIDER A CUBIC MILE *of sea water: in it you will find up to eighteen million tons of magnesium, 25 tons of gold, and large quantities of other chemical compounds embracing sodium, sulphur calcium, potassium, bromine, and chlorine. All these and more, of course, plus dissolved salts of silver, aluminum, radium, nickel, iron, chromium, and even that rising star of the atomic age—uranium. And there are 300 million cubic miles of seawater. (Courtesy* This Day *Magazine)*

is still largely the frontier of the chemist. Hope for extraction of valuable minerals on a large commercial scale hangs upon the results of recently-expanded research in this new field, and particularly the development of promising methods of handling dilute solutions, such as those involving ion-exchange techniques.

Far Reaching Effects

Quietly, and while most of us have been craning our necks at "sputniks," a good deal of actual progress has been made in wringing useful secrets from the sea. Technical and industrial journals report plans for the construction of several new plants or facilities for the extraction of sea water minerals and chemicals. Scientific papers cite continuing research and discoveries that may soon have far-reaching effects.

Extraction of various substances from sea water is not, of course, basically a new idea. Because sodium and chlorine ions (electrically charged atoms or groups of atoms) represent 85 per cent of the dissolved salts in the ocean, they are the easiest to extract. Sun evaporation can do the trick. Thus sodium chloride, or table salt, became the first mineral compound removed from the ocean and used by man.

Back to the Chinese

Salt from the sea is mentioned in Chinese writings dating back to 2200 B.C. The Greek philosopher Aristotle describes a method of desalting sea water in his *Meteorologia,* and praises the merits of sea salt, whose variety of trace elements, beneficial to health, have only recently been rediscovered during modern medicine's quest of "a balanced diet."

Nearly all early methods of producing salt, in Greece, Rome, Egypt, and the Orient, involved solar evaporation; that is, the sun drawing off water from diked, shallow-water areas leaving a salty residue. This simple process is still in use in many parts of the world, notably in Japan, the Near East, India, the southern Bahamas, and Puerto Rico.

Development was Slow

Although early American colonists made salt from sea water as early as 1680, crude soda and potash were obtained from the ashes of seaweed in Scotland in 1720, and iodine and magnesia were recovered in Europe in the 19th Century, not much attention was paid to the ocean as a mineral and chemical source until 1923. In that year magnesium chloride and gypsum were produced from the bitterns (mother liquor in salt-works after the salt has crystallized out) of San Francisco Bay water. Three years later, the first sea water bromine was recovered on a commercial scale from

the bitterns of the same plant, and industry began to take notice.

Soon (1931) the Dead Sea, famous since Biblical times for its intense concentration of dissolved mineral salts, came into the picture with commercial production of potassium chloride and bromine.

Up to this point, the majority of projects recovering chemicals and minerals from the sea depended upon solar evaporation, or upon boiling processes, for the initial concentrating of the sea's valuable salts. A few operations depended upon the concentration of dissolved substances by the action of plants or animals as in the soda, potash and iodine contained in seaweeds. Or they employed a chemical reagent—the liming of sea water to produce magnesia, for instance.

Along came Ethyl!

But it was the sharp increase in the use of anti-knock gasoline, in 1933, that really put the sea in the mineral business. Plants drawing upon subterranean brines simply could not meet the rising demand for ethylene dibromide, a necessary associate of tetraethyl lead in the making of non-complaining motor fuel.

In anticipation of such a shortage, the Ethyl-Dow Chemical Company had built an experimental plant along the Atlantic Ocean at Kure Beach, North Carolina. Here its scientists demonstrated that bromine could be extracted directly from sea water, without prior concentration of sea salts. Unique feature of this operation was the removal of a *small* amount of bromine as a gas from a relatively

POURING MOLTEN MAGNESIUM METAL, *derived from sea water, into molds. Portions of two electrolytic cells can be seen in the background. This is the final stage of the process developed at the Dow Chemical Company plant, Freeport, Texas. (Dow Chemical Company)*

large volume of water as vapor, to get certain amounts also of dissolved salts. In 1940, further demands for bromine led to the erection of a similar but much larger sea water plant at Freeport, Texas, on the Gulf of Mexico.

First Magnesium Metal

A major milestone in ocean-mining came in 1941, when the Dow plant at Freeport succeeded in producing the first magnesium metal from Gulf water, eliminating the intermediate process of obtaining magnesium chloride from bitterns. The U.S. Government, to meet emergency wartime needs, built a huge magnesium-from-the-sea plant at Velasco, Texas, designed and run by the Dow Company. Cost of magnesium production was actually slashed about 30 per cent.

Chemicals from Oyster Shells

Unfortunately, both the magnesium plant at Velasco and the bromine operation at Kure Beach became "war casualties" when peace sharply reduced demand for their products. Subsequent economics, however, proved to be in favor of sea water processes, and it was not long before the entire U. S. production of virgin magnesium and an estimated 80 per cent of bromine were coming from the seas.

MAGNESIUM HAS MANY USES. *Because it is light and easily worked, this versatile metal is favored by the makers of airplanes, motor buses, automobiles, and other vehicles. Primary magnesium production in the United States in 1957 was 81,263 short tons. Except for a small percentage, produced by the ferro-silicon process, all of it came from sea water-process plants. (Dow Chemical Company)*

While the chemical processes involved in the conversion of sea water into useful compounds and minerals are too complicated to be outlined here, it may be mentioned that magnesium, the most important of present sea-derived minerals, is taken out of sea water in an alkaline rather than an acid condition, and is finally removed by precipitation. Ten well defined steps are carried out, and they include the use of another sea product, oyster shells. These are burned to provide milk of lime which sets up the alkaline conditions.

A potentially important sea water magnesia plant is that of the Michigan Chemical Corporation, now under construction on the Gulf of Mexico at Port St. Joe, Florida. It is designed to produce 150 tons of magnesium oxide daily and is engineered to double its output when necessary. This operation will also use sea water and oyster shells, both products of the sea. These, plus fuel, power and labor, are all that is required to convert the magnesium ion in the sea water into a valuable oxide desired by industry.

Florida and New Jersey

In the Michigan Chemical operation at St. Joe, near Panama City, Florida, two principal types of product will be turned out: light-burned chemical grades of magnesium oxide and dead-burned refractory grades, the former more suited to the chemical industry, and the latter for firebrick purposes. The plant expects to begin operations in the early fall of 1959.

New Jersey has entered the sea water mineral race with a plant near Cape May. Here the Northwest Magnesite Company has built and is operating an industrial plant at which the magnesium is first extracted in the form of magnesium hydroxide, and is then converted to periclase, an oxide with properties especially useful for the lining of furnaces.

Pacific Coast Plants

On the Pacific coast, at Moss Land-

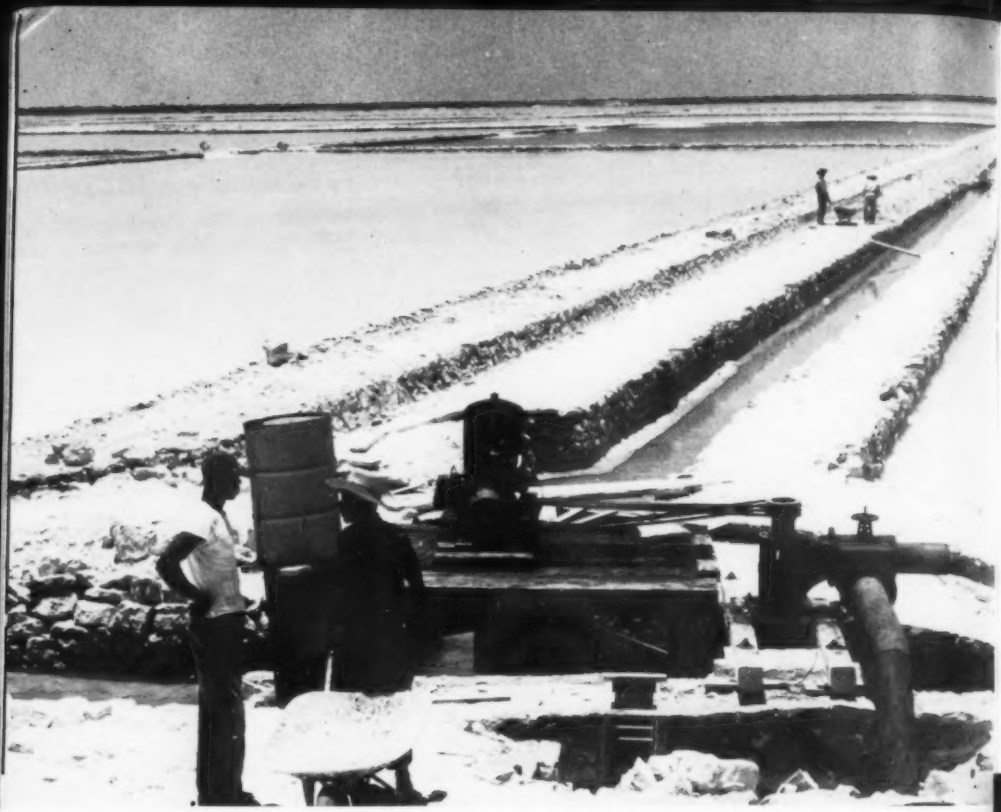
ing, California, sea water from Monterey Bay and dolomite (limestone) from the nearby quarries of Natividad are being combined to make a number of products—magnesium hydroxide and several magnesium oxides, but no metallic magnesium. The hydroxide or "milk of magnesia" is used in paper pulping processes and insulation, and the oxides find wide employment in chemical processing, and in the rayon, rubber, glass, copper and steel industries.

The Moss Landing and the Natividad plants, operated by the Kaiser Chemicals Division of Kaiser Aluminum and Chemical Corporation, also comprise the most completely integrated facilities for the manufacture of basic refractories in the United States. Basic refractories are materials used to line furnaces and kilns that must operate at temperatures up to 3300 degrees F, such as open hearth steel furnaces, cement kilns, copper converters, and other vital industrial installations.

Salt's Exalted Position

We seldom think of it as such, but common salt is, next to water itself, the most important and valuable mineral in the world. The average person requires sixteen to seventeen pounds of it a year. In addition, salt is still the most effective preservative of food.

THE SEA ASSISTS THE SEA! *In the extraction of magnesium, the mineral is taken out of sea water in an alkaline rather than an acid condition, and is finally removed by precipitation. To set up this alkaline condition, another sea product, oyster shells (burned to provide milk of lime), is used. Here oysters shells arrive by the barge load at Freeport, Texas. (Courtesy* This Day *Magazine)*



SALT PANS *at Great Inagua, the Bahamas, showing pumping equipment used to fill the large basins where sea water is evaporated in the sun. Making of salt by such a process requires a number of factors—shallow areas accessible to clean sea water, a hot dry climate, and access to shipping facilities. (Bahamas News Bureau)*

All such common salt is derived either from the sea, or from salt beds or salt lakes that are residues of former seas. But most salt that finds its way to the dinner table is a refined version of the original "sea salt," being principally sodium chloride and lacking many trace elements of medicinal value.

Yet to maintain well-being or health, both plants and animals (including man) require small amounts of certain substances found in the sea's trace elements. Modern refining processes for salt and flour have so depleted them that they are frequently artificially enriched to provide nutritional value.

To meet an increasing demand for "sea salt" as a factor in "balanced diet," a special process for extracting all of the ocean salts in a form suitable for kitchen and table use has been developed. The finished product contains about 75 per cent sodium chloride and 25 per cent other elements. It is a shapeless salt, not in crystalline form like ordinary table salt, and free-flowing. One of the principal salt plants, Trace Elements

Corporation of Houston, Texas, is located on Baffin Bay, near Corpus Christi, a Gulf of Mexico backwater which contains almost twice as much salt as the average sea water.

A Standby Reserve

While most of the world's salt needs—estimated at about five million tons a year—is met by land deposits, the seas could readily pick up this tab and more, when such sources are exhausted. Every cubic mile of sea water contains enough salt to supply the world's needs for nine years, and the oceans as a whole contain enough salt for two and a half million years, even though it were not continually replenished.

Two Valuable Products

Another important sea water mineral is calcium. Here a "middleman" helps us. Shellfish constantly extract calcium from the sea and make it available to man in their shells or in the limestone (calcium carbonate) of old shell beds. This is a centuries-old, world-wide chemical process which makes all the efforts of man seem puny in comparison.

In fact, man the chemist has only a little work to do to make the shellfish's contribution useful. By heating

AERIAL VIEW OF THE *Moss Landing Plant, in California. Here sea water from Monterey Bay, and dolomite (limestone) from the nearby quarries of Natividad, are combined to make a number of magnesium products. The hydroxide ("milk of magnesia") is used in paper pulping processes, in medicine, and in insulation. The oxides find wide employment in chemical processing, and in the rayon, rubber, glass, copper and steel industries. (Kaiser Aluminum and Chemical Corporation)*

AROUND THE CLOCK OPERATIONS. *A night scene at the Moss Landing, California, magnesia plant. The reflecting basin in the foreground is one of five tanks where the settling magnesium hydroxide slowly thickens and the soluble impurities are washed out with softened fresh water. In this facility the end products are oxides and hydroxides of magnesium, rather than the metal itself. (Kaiser Aluminum and Chemical Corporation)*

or calcinating limestone or shell he gets lime (calcium oxide) and, when he adds fresh water to this, he obtains slaked lime (calcium hydroxide), both very valuable products for industry or living.

Potassium, still another important element found in sea water, is being recovered in a salt form from the bitter liquor drained from salt ponds, after common salt has been removed. Chemists, however, still seek an economical way of converting sea-derived potassium salts into potash, the essential ingredient of fertilizers. Progress is being made in this, and also in the extraction of many lesser known minerals.

Will Sea Aid Space Travel?

Least familiar of all, outside of scientific circles, is a rare metal called cesium, one of whose sources is the ashes of certain seaweeds. Cesium is high on the list of possible rocket-engine fuels because it is easy to ionize.

Cesium could be used in rocket power plants now under study where a nuclear-powered turbine generates an electric current, creating a magnetic field which accelerates ions (charged atomic particles) of such elements as cesium to speeds reaching a fantastic 400,000 miles per hour! The ions are spewed out of the engine, and the reaction gives the rocket an enormous and sustained forward thrust. Thus may the sea play a future part even in space travel.

Sea Gold

What about constantly recurring reports that "the sea is loaded with gold"? They are true, if you are talking about the oceans of the world as a whole. Canada's Vancouver harbor, for instance, is only four miles long, a mile wide and about 70 feet deep, but it is estimated to contain a ton and a quarter of gold, worth a million dollars.

There are 300 million cubic miles of sea water and in just one of these there may be as much as twenty-five tons of gold, but it is in such minute particles as to make extraction unprofitable, although repeated attempts have been made to do so. A classic but unsuccessful example was the German *Meteor* expedition to the mid-Atlantic in 1927, with the objective of obtaining sufficient gold from the sea to pay the German war debt.

Nodules on Sea Floor

No discussion of maritime mining would be complete without some mention of metal-bearing rocks, in the form of nodules or irregular lumps, lying idle on the ocean floor. Made up of materials which have washed into the sea from the land, these nodules are brown and black pieces of stone or ore that have taken millions of years to form—often around pieces of clay, pumice, volcanic glass, or even shark's teeth or bone. In size they range from a few inches in diameter to two cubic feet.

The research vessels *Horizon* and *Spencer F. Baird,* of the Scripps Institution of Oceanography, found a rich deposit of nodules off the coast of the Tuamotu Islands, a French possession in the Pacific, during an IGY expedition in 1957-58. In addition to nickel, cobalt and copper, the nodules contained iron and manganese, the latter an important and valuable mineral of which the United States has only a limited supply.

Vacuum-Cleaning Dredge

Bringing the nodules to the surface from ocean depths presents difficulties, akin to deep-shaft mining on land, but requiring much different solutions. The method employed by Scripps scientists, using a large vacuum-like dredge, succeeded in raising boulders a foot in diameter some 1,000 feet. One dredge brought up almost 500 pounds of smaller nodules from a depth of 4,000 feet.

By vacuum-cleaning a square mile of the sea floor, in a good location, it is estimated that enough of these odd little chunks of ore could be recovered to yield about 6,000 tons of manganese, 4,000 tons of iron, and 125 tons each of nickel, copper and cobalt.

Value $500,000 per Square Mile?

In a report to the American Geophysical Union, Dr. Roger Revelle, director of Scripps, estimated that the value of such mineral deposits on the ocean floor might run as high as half a million dollars per square mile. Until additional explorations can be made, no one knows how extensive or rich these sea bottom deposits may be. Some 40 million square miles of reachable areas might be swept, but even a partial probe would be a king-size engineering job, and a very costly one. Not until land deposits

play out almost completely, is it likely to become practicable.

During the Scripps-IGY cruise "Downwind," a submarine mountain range extending southwest from Peru for 600 to 1,000 miles, was explored from the surface. Called "Nasca Range," it was not a new discovery, but previously had been known only from a few spot shoal soundings and echo-soundings. Along it were found sludge areas also containing manganese, iron, cobalt and copper ores.

Greatest Storehouse

What is the future of maritime mining? Those who have explored the possibilities, particularly in the chemical field, are not only optimistic, they are highly enthusiastic. There can be no denying that the sea is the world's greatest storehouse of raw materials, not only of minerals and elements, but also, to an important extent, of food and many other necessities of man.

The sea's largess, too, is most conveniently located. Industries which wish to draw upon sea water salts have hundreds of thousands of miles of sea coast to choose from, because the quality and mineral content of seawater is fairly stable everywhere.

C. M. Shigley, of Freeport, Texas, and a recognized expert in the field, says: "The large scale recoveries of bromine and magnesium from sea water must not be regarded as merely incidents in the record of scientific progress of the past three decades. They are indicative of a pronounced trend toward using the seas for more of life's needs.

"It is natural that this should be. The seas, bordering every continent, represent a global source of supply. They are practically inexhaustible. Total quantities of available salts reach astronomical figures and are unquestionably increasing with the daily contribution of the rivers, while other mineral resources are being depleted."

Won't be Easy

But conquest of the sea will not be easy. In addition to such chemical problems as getting rid of the water and of separating valuable elements from the sea salts, there is still one major obstacle to ultimate success in maritime mining—the cost of pumping the large quantities of sea water necessary to obtain the end products desired. While pumping is easier and cheaper than the majority of land mining methods, it still requires considerable power and fuel. Perhaps atomic power, when it becomes cheaper and more widely available, will provide the answer.

Trick of Direct Extraction

A note of caution should be sounded, however, for the overly enthusiastic. While the figures on the total number and amount of minerals in the sea are impressive, we must keep in mind their dilution. Even with all our chemical skills, the extraction of some minerals may be difficult to attain except on a laboratory scale.

However, processes for extraction exist for some elements which appear scarcely as a trace in chemical analysis of the water. Cell tissues of cer-

MINERALS ARE FOUND ALSO IN SOLID FORM. *These nodules on the ocean floor were not formed like land ores, but are made up of materials which have washed into the sea in ages past and adhered to pieces of clay, pumice, volcanic glass, or even shark's teeth or bone. Experts estimate that their value, in certain areas, may run as high as $500,000 per square mile, but a king-size engineering job faces those who would bring the nodules to the surface on a commercial scale. (Official U. S. Navy Photo)*

tain marine plants and animals have become highly efficient in concentrating rare compounds, such as the iodine salts found in seaweeds. When we can learn this trick of direct extraction from the water, we shall be nearer economic success in mining the oceans.

One of the surprising discoveries in this field was that the small, soft-bodied sea squirts, or tunicates, could extract vanadium from salt water, yet chemists were unable to find this trace element by laboratory analysis of the water itself until the sea squirt had done his job. From the same thin sea solution other shellfish and seaweeds have also been able to concentrate such elements as copper, cobalt, and silica.

Ion-Exchange Resins

Other processes offer hope for further mineral extraction. For example: ion-exchange resins, which have emerged from the laboratory stage into commercial uses, as in household water conditioners. Thus we may be able to by-pass the customary evaporation process, which is costly in power. In other words, it may not be

necessary first to separate mineral salts from large quantities of sea water and then to separate the salts from each other.

While sun evaporation of mineral salts is not so expensive, it can only be carried out along certain, generally remote, shorelines where pure sea water, low rainfall and strong sunlight are constantly available. Exchange resins operate without the need for fuel and heat to evaporate water. Here the mineral is removed from the water, at a great power saving, rather than the water from the mineral.

Somewhat more involved is another laboratory method which has not yet reached commercial application — gradual, selective removal of minerals at different rates and at different points of an absorbing column. This goes under the weighty label of "chromatographic absorption," but nevertheless may take a place in the scheme of future mineral extraction.

And the efficient functioning of the human body can come into the equation—the osmotic separation of useful food from the watery contents of man's intestines. Artificial membranes have been produced which will allow water to pass through while dissolved mineral salts are caught and concentrated. Of course, a strong semi-permeable membrane will be needed if this method is to achieve economic success, but no doubt such a membrane will be forthcoming.

Nowhere do the techniques of modern science and engineering face a more important opportunity or more stimulating challenge than in the extraction of minerals now locked in Neptune's domain. The development of the oceans' resources, like the opening of a new land, requires the patient effort of many people, plus daring financing, and a coupling of scientific research with practical know-how. Only thus may we achieve more complete use of the incalculable treasures that lie just beyond our doorsteps along the frontiers of the sea.

Contents of Volume 4

Regular paid-up members of the Foundation have already received copies of *Contents, Volume 4, 1958, Numbers 1-4,* containing a listing of all articles, authors, and classification of articles published between February, 1958, and November, 1958. Others wishing *Contents* may receive a copy without charge by writing to Membership Secretary, I.O.F., 439 Anastasia Ave., Coral Gables 34, Florida.

Fish Imitates Porcupine

By DR. JOHN E. RANDALL
The Marine Laboratory,
University of Miami

WHEN DISTURBED the porcupine fish or spiny puffer, like other puffers, can inflate its body by drawing water or air into its stomach. If it has been removed from the water, it will suck in air, and, if released, will float belly-up on the surface. Normally it inflates with water.

Before inflation, the spines lie almost flat against the body. When fully extended, however, the porcupine fish more than doubles its depth, and the spines erect rigidly, perpendicular to the body. These spines are very sharp and it is a well-advised person who dons gloves before handling such fish.

Also an Inner Armor

One must admit that the porcupine fish presents a decidedly unappetizing, not to say hostile, appearance to predators. It possesses an even better protection than the formidable spines alone would indicate. Beneath the skin, the broad basal plates of the spines are nearly in contact with one another, forming a kind of inner armor.

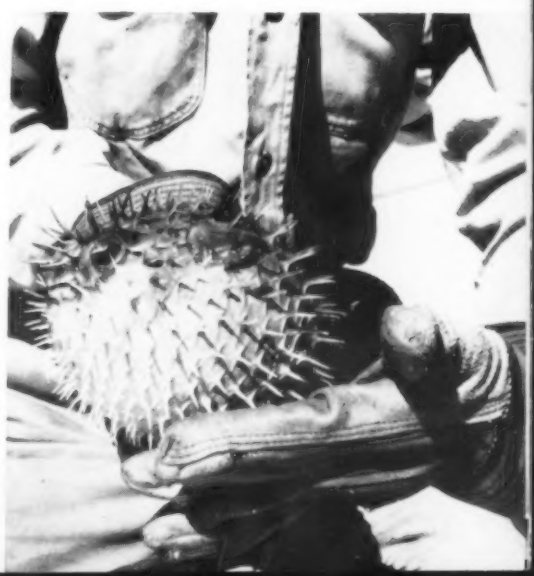
Although the spines themselves are not poisonous, humans have been poisoned from eating porcupine fishes and other puffers. The Japanese are particularly fond of the flesh of puffers. About twenty persons are killed in Japan alone every year as a result of eating them.

Toxin Comes from Fish Itself

Unlike the tropical fish poisoning known as *ciguatera,* which occurs at times following the eating of certain reef fishes such as barracuda and snappers, and is presumed to be caused by something in the diet of these fishes, puffer poisoning results from a toxin produced by the fish themselves. The toxin is said to be confined to the gonads, liver and skin, but it may be possible for the flesh to be contaminated from these organs during cleaning.

Powerful Beak

Another hazard to man comes from the porcupine fish's beak. Instead of



HANDLE WITH CARE! *The porcupine fish or spiny puffer looks like just another creature of the sea until it is disturbed. Then spines, which lie almost flat along its body, are distended and it inflates its body by drawing water or air into its stomach. It thus presents a most unappetizing, not to say hostile, appearance to predators. (Russ Kinne)*

separate teeth, its jaws have a sharp bony plate which forms a powerful beak. This beak is in one piece and does not show a joint of right and left halves as in the puffers and parrot fishes. So watch out! It can easily nip off the end of your finger.

The porcupine fish is common in tropic seas throughout the world and may exceed two feet in length. South Seas natives, years ago, used the dried skins of the porcupine fish as war helmets. Today the skin, inflated and dried, is a common curio in the Orient. In this form it makes an attractive lantern—a candle or light bulb placed inside shines through the stretched skin as it would through parchment.

Porcupine fishes and their puffer allies belong to an assemblage of highly specialized bony fishes known as plectognaths. Other examples are the trigger fishes, file fishes, trunk fishes, and the larger ocean sun fishes.

Second World Fishing Boat Meeting

SINCE 1953 there have been many new developments in connection with fishing vessels. A vessel is now a very expensive fishing tool, what with rising prices of construction, engines, fuel, labor, etc., making it imperative for owners and fishermen to pay much more regard to design. New materials, such as plastics, are being introduced. More ships are being built with transom sterns, and even bulbous bows are now used on large trawlers. Stern trawling is being adopted on large factory trawlers, and there have been many advances in the designs of steam, diesel and gas machinery, as well as in the design of propellers.

These and many other matters to promote more improvement of fishing boats will be taken up at the 1959 meeting of the World Fishing Boat Congress, the theme of which will be "Performance." It will be sponsored by the Food and Agriculture Organization of the United Nations (FAO).

The interest created by the first Congress in 1953 and by the publication of its technical reports in book form ("Fishing Boats of the World") induced the FAO to convene the Second World Fishing Boat Meeting, April 5 to 10, 1959. This Congress will be attended not only by official delegates of various nations, but also by persons connected with technical and fisheries institutions, and by representatives of private industry. It will be held in Rome, Italy.

Shrimp Landings Lower

Shrimp landings in the U.S.A. during the first six months of 1958 totaled 35.9 million pounds (heads-off), or 6 million pounds less than during the same period in 1957, according to an official report.

Bottles Versus Counters

By F. G. WALTON SMITH

IN CHARLOTTENLUND, DENMARK, a group of scientists are now providing an international service to the marine laboratories of the world which may contribute greatly to one of the most important investigations of life in the ocean, that of organic production, the rate at which plant material is produced in various depths and areas of the sea.

Underlying the problems of the unequal distribution of fishes in the oceans, the year to year fluctuations in the great fisheries and the potential but unexploited food production of the seas, lies a question of vast importance. How rapidly does the growth of plankton, the microscopic life in the sea, add to the store of vegetable material in the oceans?

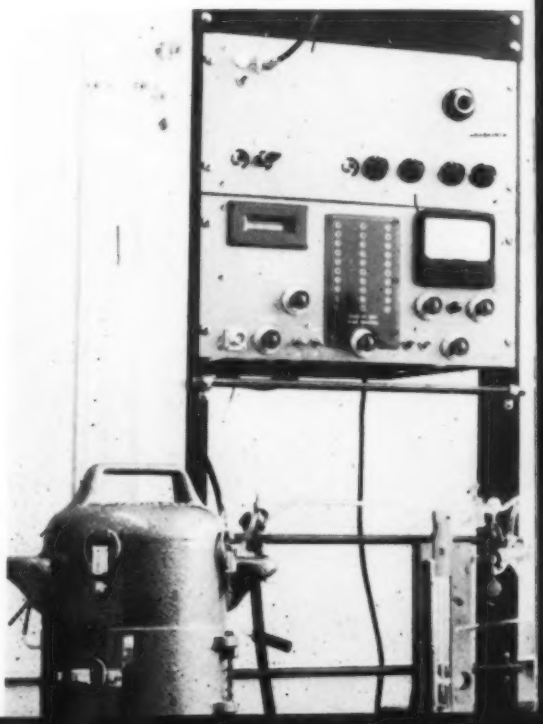
Chain of Sea Life

The food we obtain from the land may be vegetable or animal. But meat in the form of cattle subsists in turn upon the vegetation of pastures. Thus all of our food is based upon vegetable growth and this in turn, of course, upon the sunlight from which it draws energy.

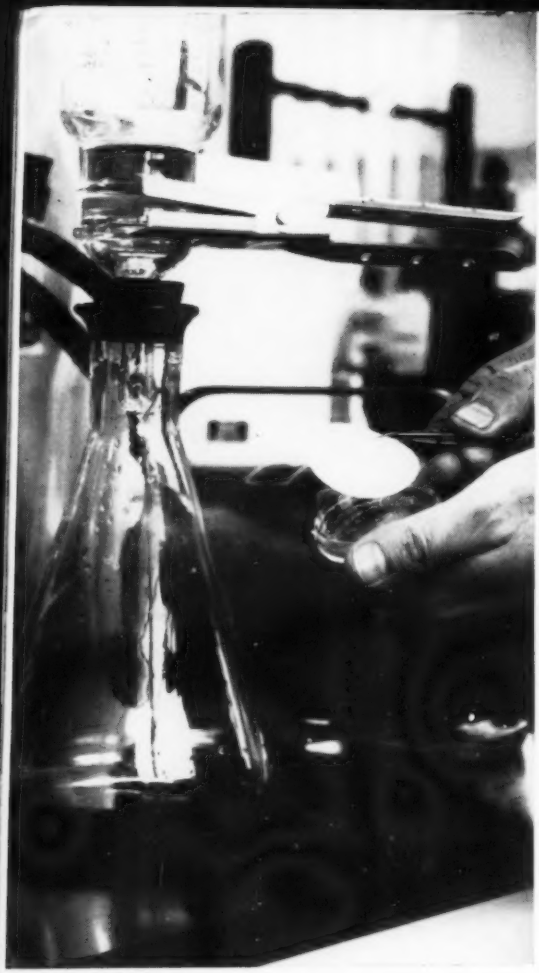
The chain of life in the sea is a good deal more complicated but basically the same. Cattle are replaced by fishes and pasture land by the plankton. So, in order to know how much food the ocean is able to produce, one must know how much plankton is produced. Essentially this production consists of the conversion of carbon dioxide and water into plant materials and, since sunlight provides the energy for the chemical conversion, it is known as photosynthesis.

Measuring Growth of Plankton

Since the plankton is minute in size and dispersed over an area far greater than the land, as well as to a depth of several hundred feet, its growth cannot be measured in the way we can



MEASUREMENT OF PLANKTON GROWTH *by the carbon-14 method involves the use of radioactive material. The instrument shown at right is used for this purpose. The Charlottenlund Laboratory offers a service which makes it possible for laboratories to measure plankton production, even though they may lack the specialized equipment. (Walter R. Courtenay, Jr.)*



THE OCEAN PRODUCES VAST QUANTITIES *of vegetable life. Although individually microscopic, the plants which make up the invisible plankton of the sea, in the aggregate, account for many times more growth than the plant life on land. But to measure this growth is difficult. The white circle of filter paper in the illustration holds plankton in the carbon-14 process of measuring ocean plant production. (Walter R. Courteney, Jr.)*

measure the growth of a tree or the yield of hay or grass. Instead, a system of sampling and chemical measurement is used. In the various parts of the ocean where the measurements are made, instruments are used to collect seawater from various depths, using great care not to contaminate it, or to harm its living plankton.

The actual measurement of production has been made in various ways One method is based upon the fact that, during photosynthesis, for every pound of carbon dioxide absorbed and converted into plant sugars and starches an equivalent amount of oxygen is *released* into the surrounding water. In daylight, however, the plant burns up part of its substance to provide energy for living. This process of respiration *absorbs* oxygen. Thus the net amount of oxygen released to the water is less than it would have been if production alone had occurred. It is the net production, in fact.

No Growth in Darkness

In order to find the total or gross production, the marine scientist also measures the amount of oxygen *absorbed* by the plankton while in *darkness*. Since no growth takes place in darkness the measure of oxygen absorbed is solely a measure of the amount used in providing energy for living, or respiration. When this amount is added to the net amount released under *daylight* conditions, the sum gives an index of the total or gross production of plant material.

In practice, the seawater sample is placed in similar glass vessels, one exposed to light, the other darkened, and changes in the amount of oxygen dissolved in the water in each vessel used measured at regular intervals. The sum of dark and light bottle changes measures the total amount of

carbon dioxide converted to plant materials, while the light bottle change alone measures the net amount of production which remains after removal of some material by respiration.

Use of Carbon-14

A second method has come into use more recently. This is based upon a more direct measurement of the carbon dioxide which is converted to plant materials by photosynthesis. It is simpler and easier to use in some ways. However, since it makes use of radioactive substance carbon-14, it requires special facilities for measuring and handling. Not all laboratories have these, and it is here that the laboratory at Charlottenlund is performing a great service, since arrangements have been made to prepare the carbon-14 solutions and distribute them at cost. Samples taken at sea may then be returned for radioactive counting.

How does the carbon-14 method work? Essentially it consists of adding a known amount of carbon-14 to the sea water sample, in the form of sodium carbonate containing a known amount of radioactive material. The proportion of carbon-14 to the total amount of carbon in the water sample is readily calculated. After a measured interval of time the water is filtered, so that all of the plankton remains behind on the filter paper. It is washed free of the carbon-14 treated water. The dried filter is then measured for radioactivity by an instrument designed for the purpose, an elaborate geiger counter, as it were. The amount of radioactivity indicates the amount of carbon-14 in the plankton. This is proportional to the amount of carbon absorbed by the plankton during the interval of exposure to the treated water and may thus be used as a measure of organic production rate.

Scientific Controversy

The relative merit of the two methods has been the subject of a considerable controversy, which has fortunately been resolved to a great extent at a symposium held by the International Council for the Exploration of the Sea at Bergen, Norway, in September, 1957. Most scientists are now in agreement that the carbon-14 method provides a fairly good estimate of net production and there is no doubt that it is more convenient in many ways. With this tool at hand it should be possible to extend productivity measurements all over the world.

Lacking facilities to prepare the carbon-14 ampoules used in this method, only a few laboratories have hitherto been able to make productivity measurements except by the relatively tedious light and dark bottle experiment. Now, by writing to Dr. Steemann Nielsen at the Danish Institute for Fisheries and Marine Research, Charlottenlund Castle, Denmark, they will be able to obtain the necessary materials for the bare cost. It is hoped that by taking full advantage of this, the smaller marine stations of the world will be able to join in the international efforts of science to solve one of the basic problems of the sea.

Science of the Sea in Books

Books for the general reader are indicated thus, **(Gen.)**; those of interest chiefly to professional scientists, **(Pro.)**

ON THE DYNAMICS OF EXPLOITED FISH POPULATIONS **(Pro.)**

RAYMOND J. H. BEVERTON and SIDNEY J. HOLT. Ministry of Agriculture, Fisheries, and Food, Fishery Investigations series II, volume XIX. Her Majesty's Stationery Office. London, 1957. 533 pp. £6/6/0 or $17.64.

Theoretical ecologists and fisheries scientists alike have watched with great interest the progress of the authors on the development of "a mathematical theory of fishing." Starting with the assumption that an unfished population would exist in a steady state, and making a few not unreasonable simplifications, the authors have constructed a model fishery which would extract the most profitable continuous yield available.

The information furnished by this model is complete from the proposed minimum net mesh and number of fishing boats, to the changes in yield to be expected for the first few years after the adoption of the proposed fishing methods. That the simplifying assumptions were happily chosen is demonstrated by the correspondence to the theoretical model of two actual fisheries, the plaice and the haddock. The theoretical model cannot be used strictly as constructed for many other fisheries. The "steady state" assumption obviously is not adequate for those fisheries which experience the phenomenon of dominant year-classes, or for complex fisheries like the Pacific salmon. The point to be remembered is that it may be possible to construct a satisfactory model for these complex fisheries by modifying the basic assumptions. The assumptions and modifications must be chosen with an eye to the physiology and behavior of the fish in question.

To the casual page-flipper, this book will seem a mass of mathematical formulae, and it is definitely not for the general reader. The dust-cover states that the authors "have written with sympathy for non-mathematicians"; this reviewer feels an even deeper sympathy. However, the mathematics necessary to the main part of the theory is not difficult. The more complex formulations are usually the result of a conversion from one form to another equivalent form, as from yield in number of fish per year to yield in grams per year. In the extreme cases, it may be worth considering the expense of a "translation" from mathematics to standard English. This is one of the classics of fisheries research and quantitative ecology.

P.J.W.

SEAMANSHIP **(Gen.)**

T. F. WICKERMAN. Philosophical Library. New York. 1956. 192 pp. 69 illus. $10.00.

This little volume on seamanship is published in England for the use of "Efficient Deck Hands and First Year Apprentices." As nearly as this reviewer can ascertain, these are the British equivalents of Deck Boys and Cadets in the American Merchant fleet.

The author states in the introduction that his book presupposes no earlier knowledge of ships, deck seamanship or small boats. On this premise, eleven chapters attempt to build up a working knowledge and vocabulary of ships, their equipment, ship routine, deck work, cargo handling, safety requirements and the rules of the road.

Certain of the chapters, such as that on "Tides and Buoyage" will be of little value to American readers because of the differences in the buoyage systems of the two countries. Also, in the chapter on "Compass and Steering," the reader may find that the British Merchant Marine still adheres to the point and quarter point system, whereas in the United States this has been deserted in favor of orders given in degrees.

Despite tradition, the degree system is far safer for experienced and inexperienced helmsmen alike. Similarly, orders to the helmsman in this country, in the interest of clarity, are now given as "right" and "left" instead of "port" and "starboard."

This book is not a text or manual on seamanship but, as the author states, is a compilation of "facts" concerning ships and seamanship. While intended for the apprentice, every yachtsman, and even the professional, will find something of interest in this little volume which is a mine of information crowded into 192 pages. The illustrations are clear and well chosen and the text is lucid and interestingly written.

Unfortunately, the Philosophical Library has continued its practice of charging excessive prices for English books and probably few readers will be willing to pay the steep price which the publishers have placed on this little volume. G.L.V.

VOICE ACROSS THE SEA **(Gen.)**

ARTHUR C. CLARKE. Harper & Brothers. New York, 1958. 208 pp. $3.75.

The laying of the cable across the Atlantic in the last half of the nineteenth century was a milestone somewhat analagous to that we shall experience when we finally bridge interplanetary space. The story is fascinating and adventurous, and Mr. Clarke has told it well, perhaps because he has made no attempt to make it a detailed history of submarine communications, and also because he has included many odd bits of "frosting."

From 1840, when the electric telegraph entered the world of commerce, until 1956, when the first submarine telephone cable was laid

LAYING THE ORIGINAL ATLANTIC CABLE *was an engineering feat of the first magnitude. This water-color, made on the scene by Robert Dudley, shows the cable fleet leaving Ireland, in 1858, amid noisy ceremonies. (Metropolitan Museum of Art, on loan to Smithsonian Institution)*

across the Atlantic, the tale changes from physical adventures of bold and daring men, who won and lost fortunes in great gambles against natural forces, to a report of scientific adventures in electronics laboratories. The transference is easy, and, with the exception of Chapter 20 (appropriately called *Technical Interlude*), the book does not demand much knowledge of electricity. Even this chapter can be read comfortably by an individual with the background of, for example, a hi-fi enthusiast.

The book is accurate. This is to be expected from a science-writer of the stature of Mr. Clarke. His interests lean towards both space (and science fiction) and the ocean. He is an expert skindiver and has written two books about coral reefs. Mr. Clarke's other nonfiction books are concerned with space. A.F.

A TREATISE ON LIMNOLOGY, VOLUME I: GEOGRAPHY, PHYSICS, AND CHEMISTRY (first of two volumes). **(Pro.)**

G. EVELYN HUTCHINSON. John Wiley & Sons, Inc., New York. 1957. 1015 pages, including index. $17.50.

Limnology (the scientific study of lakes and ponds) and Oceanography have developed into independent sciences in the very recent past. Even today, because of their wide scopes, they still are considered as meeting grounds for physicists, chemists, geologists, and biologists. Of the scientists who are actively studying events which characteristically occur in the lakes and oceans, very few have a profound knowledge outside their own sphere.

G. Evelyn Hutchinson, with a paramount knowledge of the total field, with his productivity and the ease with which he tackles chemical, biological, and physical problems — certainly the most outstanding scientist in his field—reminds us of the scientific geniuses of the Renaissance, when a scientist did not just specialize in a narrow field, but contributed to several different disciplines. Hutchinson is a naturalist in its best sense. To him, the system which the layman calls a lake and which the specialist subdivides again and again is indeed a unit, exciting from every angle.

In this volume, the first of two which will comprise a general treatise on Limnology, Dr. Hutchinson has drawn on his wide knowledge of the events which occur in lakes. We oceanographers are most grateful. The links between Limnology and Oceanography are general, and many phenomena are the same in both environments; others, many others, are very similar. Some of the phenomena were originally detected in the lakes, were subsequently found in marine environments by the oceanographers who investigated them, and, strangely enough, the techniques developed were then applied again in the lakes.

In general, the hydrodynamical aspects of Oceanography are more highly developed, while in Limnology, the chemical aspects are more advanced. In the future, it will be necessary to increase the collaboration between the sciences and this will result in more fruitful growth of each science. The formation of the American Society of Limnology and Oceanography (ALSO) was a step towards this goal.

The book is written concisely, for the most part, has an excellent bibliography, an index of lakes, and a general index. It is hoped that the rather high price will not hamper the wide distribution of this book among limnologists, oceanographers, other scientists, and persons who are interested in the science of an important part of our planet. F.F.K.

About The Authors

DR. JOSE A. SUAREZ-CAABRO

Except for three years as a sugar chemist in the interior of Cuba, Dr. Suárez has spent practically all of his adult life in educational work, chiefly the natural sciences, with emphasis on marine biology and oceanography. Following his graduation as a Doctor of Natural Science at the University of Habana in 1951, Dr. Suárez continued his studies at the University of Florida, the Marine Laboratory of the University of Miami, and with various branches of the U. S. Fish & Wildlife Service in Florida, and aboard F. & W. L. vessels in the Gulf of Mexico.

In 1955 he was appointed by UNESCO to carry out studies in oceanography and marine biology at the University of São Paulo, Brazil. During this duty he visited scientific centers in Uruguay, Argentina, Chile and Peru in order to become acquainted with the oceanographic work being done there.

Returning to Cuba, Dr. Suárez was appointed Professor of Zoology at the University of Villanueva, at Marianao, near Habana. Since 1957 he has shared his teaching work with directorship of the Marine Laboratory of this University. Dr. Suárez has published various scientific papers in marine biology and fisheries, especially on the marine plankton of Cuban waters.

Any Old Canned Oysters Around?

If you have any cans of oysters packed before 1945 around the house, you may be able to help science. The Food and Drug Administration in Washington has been studying the amounts of radio-activity in foods. There has always been a certain amount of it "naturally-occurring." Since the first atomic bomb blast in 1945 a certain amount of man-made radioactivity has been added to exposed foods.

But oysters canned prior to 1945 presumably would show the natural kind without any additions. By comparing this product with oysters canned since that time, some measure of the additional radioactivity added by man could be determined.

A single can is enough for the test. It should be sent, with approximate date of purchase, to the Oyster Institute of America, 6 Mayo Avenue, Bay Ridge, Annapolis, Md., or to the Food and Drug Administration, Washington 25, D. C.

Progress

IN THE SHORT PERIOD of its life, *Sea Frontiers* has now reached a circulation of 35,000, not all of whom are members. They are drawn from the United States, Canada, Central and South America, Great Britain, Australia, France, Germany, Italy, Denmark, Sweden and Norway, as well as a few from the Pacific Islands and the West Indies. Continued improvement will be possible with growth of active membership. It will be seen in better service, with more articles in the Bulletin of high interest and authenticity and, eventually, a monthly issue in full color.

Members are joined in these aims and they are urged to make progress possible by taking the small effort needed to enlist new members. To those who are not members, but whose interest and curiosity lie in the sea and the spirit of discovery, there is extended an invitation to participate by simply mailing a card. The ocean is our last frontier and its exploration still under way.

The editor will be glad to consider for publication articles and illustrations covering explorations, discoveries or advances in our knowledge of the marine sciences or describing the activities of oceanographic laboratories or expeditions in any part of the world.

The International Oceanographic Foundation

"To encourage the extension of human knowledge by scientific study and exploration of the oceans in all their aspects, including the study of game fishes, food fishes, ocean currents, the geology, chemistry, and physics of the sea and the sea floor."

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The Foundation was established by a group of saltwater anglers, yachtsmen, shipowners, marine scientists and others interested in the scientific exploration of our last frontier, the ocean. Its objectives are to provide support and encouragement for marine research, exploration and discovery and to promote the collection and dissemination of scientific knowledge about the ocean.

Qualifications for membership are an interest in the oceans and a desire to extend and develop scientific research and exploration into them. Support given to research through personal activities or donations is recognized by the Foundation through the following classes of membership. Members are those who make annual contributions of $5, Fellows $25 annually; Associates $100 annually; Life Fellows are those who contribute $200 or more or who have otherwise helped to advance the purposes of the Foundation; Sponsors who contribute $1,000 or more; and Patrons who contribute $5,000 or more. Corporate Associates contribute $1,000 annually.

According to a ruling of the U.S. Treasury Department, donations made to the Foundation are deductible in computing taxable income as provided for by the 1954 code.

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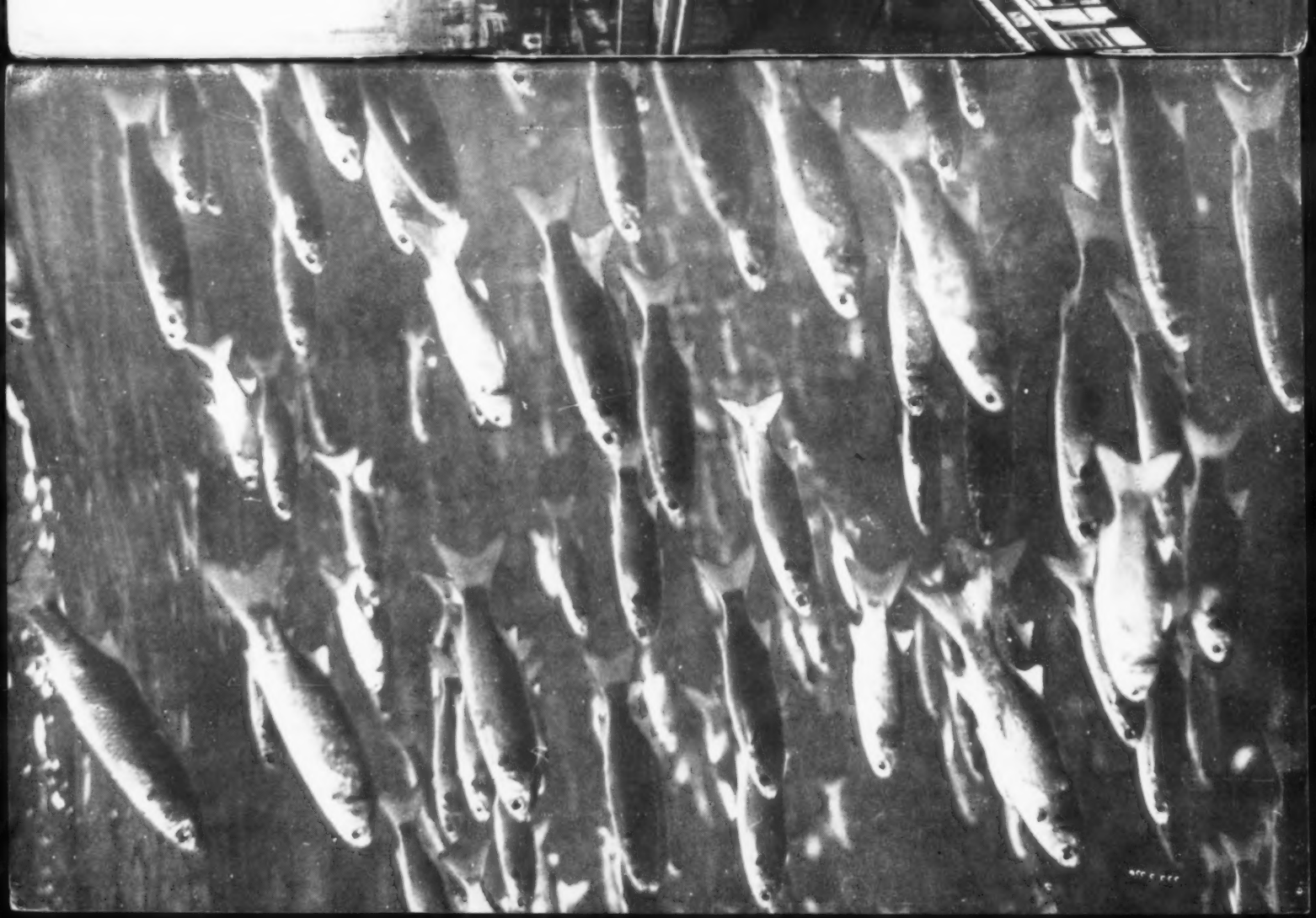
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